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SCT SYSTEMS CONTROL TECHNOLOGY, INC.

2300 GENG ROAD P.O. BOX 10180 PALO ALTO, CALIFORNIA 94303-0888 (415) 494-2233

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FORCE LEVEL AUTOMATED PLANNING SYSTEM
(FLAPS)

ANALYSIS OF VIDEO DISK AND COLOR HARDCOPY TECHNOLOGY FOR MISSION PLANNING APPLICATIONS

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Prepared by:

Len Abrams
Systems Control Technology, Inc.
Mission Effectiveness Department

Approved by:

Alan R. Stephenson

Alan R. Stephenson
FLAPS Project Manager

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This document was the result of three months investigation to determine the present and future optical disk map technology and to recommend available off-the-shelf hardware and software capable of supporting tactical attack aircraft mission planning and combat mission folder preparation. This report was developed by Systems Control Technology, Inc. Palo Alto, CA for HQ USAFE Deputy Chief of Staff for Operations. The main objective of this study was to determine a hardware/software combination that could use available off-the-shelf computer equipment and military and civilian color map data base files and currently available Government owned automated mission planning products to produce an automated mission planning system that generate a combat mission folder (CMF). It was desirable that the resulting system could produce a single CMF with colored strip map charts and selected radar predictions within 15 minutes or less. A market survey was conducted and included a technology review of: optical map disk capabilities, hard disk drive options, color hardcopy units capabilities and limitation, and available small, but powerful front end computer systems. Also, included is a review of the available mission planning workstations.

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1. INTRODUCTION AND SUMMARY

In today's operational environment, paper maps and charts are used extensively during the mission planning process for route planning and combat mission folder (CMF) preparation. For tactical attack aircraft, the mission planner utilizes paper maps to select and review his flight path, to obtain navigation information, to determine radar predictions, and to cut portions of the maps to build his CMF. The developments and advances in optical disk map technology coupled with automation of mission planning functions at the squadron level make it feasible to automate the production of CMFs and to manipulate maps via a computer system. The purpose of this study was to review present and future optical disk map technology and to recommend hardware/software capable of supporting tactical attack aircraft mission planning and CMF preparation.

There are several issues related to the use of optical disk map technology in the mission planning process. These issues deal with data sources for maps, digital representation versus analog representation of the maps, video monitor and hardcopy resolution, and processing/manipulation of maps. Depending on requirements and the target host computer system, different approaches can be taken for the implementation of an optical disk map and CMF preparation capability. The intent of this study was to provide sufficient data to allow selection of a hardware/software configuration which supports the use of optical disk maps during the mission planning process. A summary of the study results is as follows.

- There are analog as well as digital sources of maps. For digital products, no standards have been established by the Defense Mapping Agency (DMA) nor is there presently a set of digital map products usable for this application. Analog map products, on the other hand, are available from DMA in a standard format for various parts of the world.
- Manipulation of map images is required for effective CMF preparation. Mosaics of multiple map images as well as rotation and scaling of the image are required for CMF production. The manipulation requirements in turn dictate digitization and digital processing of the map images.
- High resolution graphics display devices are preferred to support graphics overlays used in the mission planning process.
- A thermal printer is recommended for hardcopy output. This recommendation is based on reliability, maturity of the technology and quality.
- A printer interface is required to buffer hardcopy output. This device allows workstation operations to be done in parallel with printer operations. The device can also be used to provide hardcopy screen output of other devices such as the Tektronix 4125.
- Utility software to manipulate the video maps and digital images must be developed. At the present time, commercially available software does not meet the map manipulation and CMF preparation requirements.

2. SCOPE AND OBJECTIVES

The objective of this study was to define hardware/software configurations needed to incorporate optical disk maps into the mission planning process. This includes the use of an optical disk map as background for route planning and automatic creation of CMFs.

The scope of this effort included: identifying requirements associated with the use of optical disk maps for tactical aircraft mission planning; identifying hardware/software components needed to support optical disk map usage and CMF preparation for the Tactical Air Forces (TAF) Cromemco-based Mission Support System (MSS) and the MicroVAX II-based Fairchild Mission Analysis and Planning System (MAPS); defining requirements for radar prediction on the MSS and MAPS hardware suites; review of some existing systems which produce CMFs; and an analysis of the various map products (digital and analog) for mission planning.

To meet the objectives of this study, the report is organized as follows:

- Section 3 explains the advantages and concept of usage for the proposed new capabilities.
- Section 4 delineates the functionality necessary to perform the needed operations.
- Section 5 describes the envisioned mission planning workstation and shows the interaction between the components.
- Section 6 compares the various types of optical disk technologies and their applicability and discusses the available analog and digital disk drives. Disk technology applicability leads to the discussion of image processors. The capabilities and limitations of various color hardcopier technologies are then shown. The section also addresses the issue of which type of printer interface is applicable. Section 6 then analyzes the available color printers and interfaces and concludes with component recommendations.
- Workstations that are presently available and might be used as the core of the proposed mission planning workstation are compared in Section 7.
- The Appendicies show additional available hardware and software components, and a Glossary concludes the report.

3. OPERATIONAL ADVANTAGES OF OPTICAL DISK MAPS AND COMPUTER GENERATED HARDCOPY

There are two areas in the mission planning process where optical disk maps serve to enhance planning effectiveness and reduce planning time. The first is in the use of the optical disk map as a background display during the route planning process. The second is the use of the optical disk map to automate the CMF preparation process.

The present MSS uses a large digitizer board with a paper map mounted on it for graphics input. The operator positions the cross-hairs of the digitizer board's graphics input device over a spot on the map, and the cross-hair's position is transferred to the equivalent geographic position in the MPS software. The operator must then go to the computer's video screen to observe the position of the resulting curser that was transferred to the screen from the digitizer board.

Replacing the MSS digitizer board with an optical disk capability has many advantages. The obvious ones are that the optical disk hardware is smaller and that additional space will be gained by replacing paper maps with the disk. It would not be wise to say that there is no longer a requirement to process paper maps, as every unit will have to maintain a manual planning capability in case of loss of power, etc.; however, the quantity could be reduced significantly.

Operationally, the advantages are numerous. When the planner starts to mission plan, he can stay in one place and have rapid access to any information he may require. The numerous trips to intel to view the grease pencil order of battle will be a thing of the past. With the graphic display the planner can select waypoints for his ingress/egress route, allow the computer software to determine the route, review his route, and make manual modifications to the route. With an optical disk map capability, the planner will have, displayed in background, DMA maps to aid in the flight path selection and review. The maps will be the same maps and charts that a mission planner is accustomed to using.

As the planner manually selects his route (or allows the computer to give him an optimized one), he can elect to graphically display all threats along his route or selectively choose only those that he desires. As he selects the turn points, the coordinates will automatically be entered on his Form 70/691, thereby eliminating transfer errors. If the aircrew is using airborne radar for navigation or weapons delivery, he could now automatically generate a radar prediction of his turn point, offset aim point, or target. This would enable him to determine if the point of interest would "show" at his planned altitude and heading. When he is satisified that his planned route is the safest one possible that still meets mission objectives, he can automatically generate a hardcopy combat mission folder. No longer will he have to gather up numerous paper maps and assorted paraphernalia required to make a combat mission folder.

The end result of the optical disk capability is that the planner will have rapid access to all necessary mission planning materials. This will not only decrease mission preparation time, but also increase accuracy.

4. FUNCTIONAL REQUIREMENTS AND ISSUES

The purpose of this section is to summarize the major functional requirements associated with the use of optical disks as an aid in automated mission planning. The subsequent sections will then address the ability of the current and future technology to meet these requirements.

The mission planning workstation must generate a clearly readable and usable CMF output, at a reasonable cost, while enabling future improvements to be made easily. The field of view of the output map must be large enough to encompass a typical route leg when displayed at a scale that depicts the features needed by the aircrew for the elevation being flown. The route leg shown on a CMF page must have the proper annotations shown prependicular to the direction the leg will be flown. A balance between copy clarity and excessive image storage requirements, computation time and copier cost must be arrived at. TEMPEST certification of the equipment versus containment of the facility's emissions is an issue, as is the method of tempest certified equipment design. More detailed discussions of each of these requirements are presented below.

4.1 MAP BACKGROUND

In order to aid the planner during the route planning process, the flight planning workstation must display a map background of the area of interest, overlayed with the planned routes and whatever other information the system normally produces.

4.2 HARDCOPY OUTPUT

The mission planning system must be capable of producing a paper output with the route legs shown per USAFE Regulation 55-125. This standard is often deviated from in minor ways such as the size of the map sheets, but provides a good set of guidelines. The routes shown in the hardcopy output should include the map background described in Section 4.1.

4.3 FIELD OF VIEW

The field of view of the hardcopy map output should be large enough to encompass a typical route leg, about thirty miles, or eight inches on a 1: 250,000 scale map. The long axis of the map sheet should be at least six inches to provide the aircrew with a useable CMF product without pasting several sheets together.

4.4 ROTATION

The map background and/or annotations must be rotatable so that the annotations in the hardcopy are right-side-up when the flight leg is facing up, per USAFER 55-125.

4.5 RESOLUTION

Resolution requirements impact the video display and the hardcopy output. The resolution must be sufficient to show contour lines, but the map need not be indistinguishable from a standard DMA paper map product. The requirement is to make a map with enough clarity and detail to enable the aircrew to navigate in the same manner as is done when the planning is done manually, rather than to reproduce the original paper map.

4.6 TEMPEST

Tempest certification is a requirement for an operational system, but may not be a requirement for a prototype system. Tempest certified components should be utilized where they are available.

5. GENERALIZED SYSTEM CONCEPT

Figure 5-1 shows the generalized concept of the mission planning workstation. Map images stored on optical (or magnetic) disks are used to provide a background for the routes generated on the computer by the mission planning software. Map indexing and manipulation software residing in the computer is used to bring the appropriate map images from the disk into the image processor so that the routes and annotations can be overlayed on the maps displayed on the RGB monitor. Under control of the computer's map indexing and manipulation software, the image processor abutts several map images together to form a mosaic with a larger field of view than shown on each image from the optical disk. The video/graphics processor also rotates and scales the background and route overlays and displays the resultant maps on the RGB monitor. Combat Mission Folder hardcopy output is either "captured" from the video signals driving the screen by an RGB interface and copied on the printer (while the computer is freed to perform more mission planning tasks) or the CMF image is sent to the printer via a digital interface

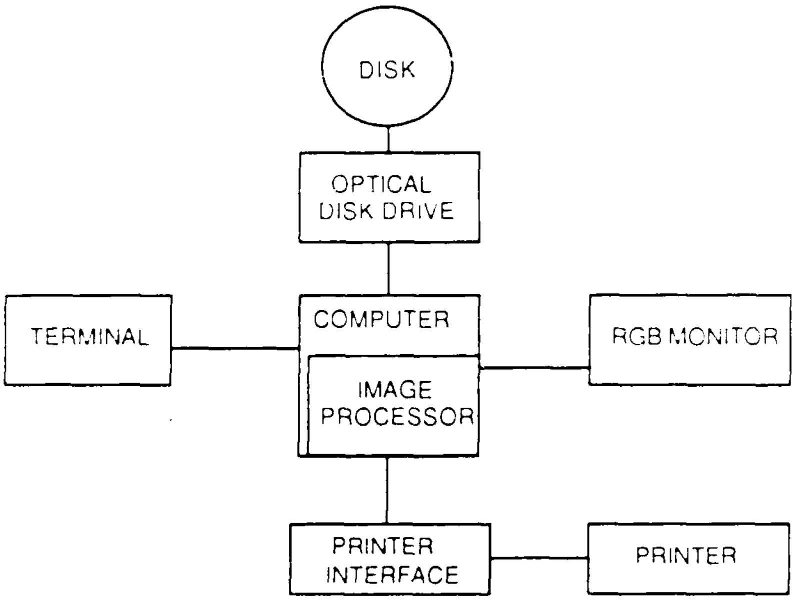


Figure 5-1 Major Hardware Components For A Mission Planning Workstation

6. HARDWARE COMPONENT TECHNOLOGY REVIEW

This section analyzes the capabilities and limitations of optical disks, image processors and printers. The basic technologies are analyzed first and then the specific commercially available devices are reviewed. The section concludes with recommendations of the technologies and components most useful for this application.

Section 4.6 stated that TEMPEST may be a requirement for an operational system. The trend among some agencies seems to be moving toward containment of the signals where possible rather than TEMPEST certification of all equipment within a facility. With this trend and Section 4 6 in mind, the study points out which items are available in TEMPEST versions and highlights both the commercial and TEMPEST costs.

6.1 OPTICAL MAP DISKS

Optical disks come in several technologies, capacities and formats. The most important aspect of the disk is the operational capability it provides in a mission planning system, rather than its method of data storage. This report divides the different types of disks into the ways they may be used, rather than by the technical aspects of their data storage. Considerable attention is also given to map disk availability.

The most familiar optical disks are the 5 inch diameter CDROMs used primarily to store audio. They can be used to store video information, but their capacity is relatively low so, if they are used to store video data, the information is usually stored in compressed digital form. In this form, a disk can hold about about 550MB. The disks are stamped from a "master" similar to phonograph records and are read-only devices

The next most often seen optical disk is the 12 inch diameter Laserdisc. Also a read-only device and made by the same process as the CDROM, it is most often used used for storage of commercial video that may be viewed on a television receiver. This is the format used by the present DMA disks.

A writable disk has the advantage of allowing the workstation operator the ability to easily update changing areas on the map background. The same technology that is used to make the read-only master can be used to make a write-once-read-many (WORM) drive. WORM drive disks come in various sizes such as 5, 8 and 12 inches.

There are two basic methods of map storage on optical disks, analog and digital. Analog disks may be digitized by the mission planning system to add operational capabilities. These two methods of map storage are discussed in separate sections below.

6.1.1 Analog Map Storage

Analog, or video, disks are a mature technology and low cost disks and drives are available commercially. The videodisks contain images of television-quality resolution. The capacity of a 12" Laserdisc is 54,000 images or "frames". The DMA videodisks are of this type. Color fidelity is good so that fine variations in the colors of the image can be detected. This is not as much of a requirement for map images as it would be for general photography. For map images, the minimum number of colors required is about 128 although some systems use as many as 16 million to approach true analog color. The 128

or so arbitrary or "pseudo" colors are an approximation of the "true" colors found in a photograph or true image.

Typically a DMA videodisk frame contains a large amount of redundant information since the map images overlap by as much as fifty percent in latitude and in longitude. The overlap is used so that the user can "roam" around the map by displaying an adjacent image that covers some of the previous image's area.

One disadvantage of an analog image is that a digital computer cannot process it. When a video image is used as a background for graphics overlays, such as flight paths, the graphics and video images are combined without the computer knowing the information content of the analog image. The computer cannot rotate the image to get a route leg into a desired position, nor can it scale the image or "roam" around the map other than by selecting a different image or "frame" that may be of a more appropriate scale or area. The image must be digitized to do roaming, scaling or rotation.

The frames can be stored on analog disks and digitized as needed by sampling and quantizing the analog signal as the horizontal lines that make up the image are output from the videodisk to form a screen image. A frame can be digitized in 1/30th of a second. Average access time for an arbitrary frame is about 0.5 seconds. Adjacent frames at the same latitude are typically accessed in much less than 0.5 seconds.

6.1.1.1 Usability of Single Videodisk Frames for CMFs

A study of a "typical" flight scenario was made to see if a CMF could be created using the standard individual map frames resident on the DMA disks. The object was to find out if typical navigation routes would fit on the existing DMA map background images in a way that would enable generation of CMF map pages without digitizing or rotating the frames. This section discusses the findings produced by the videodisk CMF study.

The low altitude parts of the route are the most critical as far as map scale is concerned. The pilot must have a map with the features he needs at that portion of the flight. The most desirable scale for the low level parts of the flight paths was considered to be 1:250,000. Flight legs are kept to 10-30 miles during this phase to minimize predictability of the path.

The DMA Laserdisks have images of small sections of conventional paper maps. The field of view (FOV) of each image is kept small (3x2 inches, or 6x4 inches on the paper map for example) to avoid distortion of the image when taken by the camera. A typical low level flight leg including parts of the previous and subsequent legs must fit on each CMF map sheet. The 6 inch FOV is an image of a 6"x4" section of a paper map. It was found to be too small for a CMF map sheet (each sheet should be about 8" x 5"). A 1:500,000 scale map could be scaled up by a factor of two to simulate a 1:250,000 scale map with minimally acceptable CMF map size and detail. The main problem is that at 1:500,000 a 30 mile leg would take 4.4 inches without showing the ends of the previous and subsequent legs, so it should be very difficult to find images that would display an arbitrarily placed leg somewhat centered on a 4x6 inch field of view.

The goal was to find out if typical flight paths would fit on the single DMA map background frames in a way that would satisfy the two CMF requirements listed below. Since many legs are too long to fit on one hardcopy page, an additional objective was to

see if maps could be found that would not cause segmentation points to be inserted too often for the cases that would not fit on one map sheet.

The two requirements of the layout study were:

1) A 1:500,000 scale chart be used for low level flight regions.

2) The legs run generally down the center of a page.

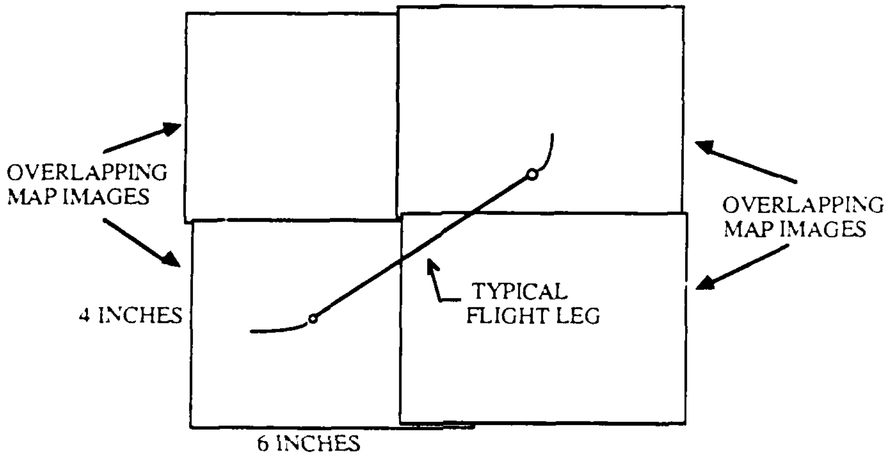


Figure 6.1.1.1-1 Videodisk CMF Images

The results showed the need to combine several images to produce a CMF map. Figure 6.1.1.1-1 shows a typical flight leg that illustrates the problem. The legs of an arbitrary flight path are not located near the center of the frames even when the frames overlap somewhat. Even short legs that would fit easily on a centered 3 inch field-of-view would not fit on any of the four 6 inch field-of-view frames that contain parts of the leg as shown in Figure 6.1.1.1-1. In short, no reasonable CMF could be layed out for any of the typical routes using 1:500,000 scale maps. Thus, it was concluded that one requirement of a video disk mission planning system is that frames be combined into a video mosaic either in hardware or software to form CMF pages.

6.1.1.2 Video Mosaics

Mosaicing of several video images together can overcome the FOV limitations described above. The mosaicing is accomplished in a video processor by piecing several digitized video images together as shown in Figure 6.1.1.2-1. The frames are overlapped by computing the positions of known latitude/longitude crossings common to overlapping frames, and entering the frames in the computer's memory accordingly.

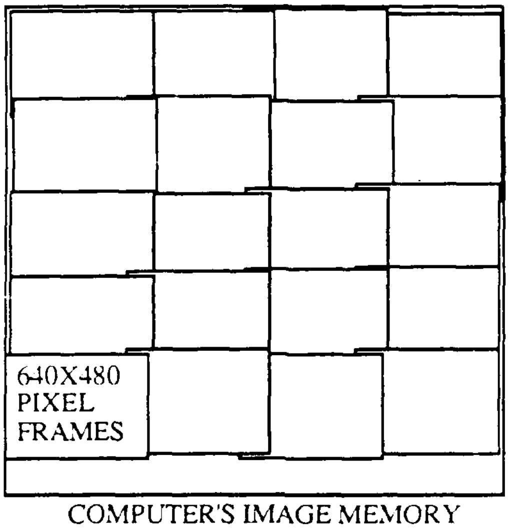


Figure 6.1.1.2-1 Video Mosaic

6.1.1.3 Image Rotation

It is important to be able to rotate the annotations or the underlying map image so the annotations are perpendicular to the route leg in the direction of travel. Since flight legs are at arbitrary angles relative to map frame axes, as shown in Figure 6.1.1.1-1, image rotation is a desirable feature for the image processor. Rotation of an undigitized video image is impractical, since the relative positions of viewable features in a video image are not known to the computer. A video monitor refreshes areas of the screen in an unchanging order independant of the information to be displayed in any area. Parts of a character or other object may be contained in several of these areas of the screen. An image is displayed by "writing" horizontal lines that vary in color and intensity along the length of each line. The picture is the result of several hundred of these horizontal lines stacked vertically on the screen. The color and intensity information contained in these lines in a video system is represented in analog form (a varying voltage as the horizontal lines are swept across the screen) and can not be manipulated by a digital computer. Unless the image can be digitized (via use of a digitizing video processor) special fonts for each desired angle would have to be drawn and positioning software would have to be written to align the text at arbitrary angles relative to an unrotated background map. The rotated text would be more difficult to read on the video screen unless software was written to input unrotated text and rotate it upon placement on the map image. The most practical solution is digitizing the image to rotate the underlying map.

Rotation of the digitized image in software can be very time consuming, sometimes taking twenty seconds or more. Fortunately, some image processors can speed the process dramatically. For example, the Parallax 1280 can rotate an image at 12 million pixels per second. An image of 1280x1024 pixels could be rotated in a tenth of a second

provided no new images had to be fetched from the disk. In practice, new images may have to be brought in depending on the size of the rotated area and the angle of rotation, so the time will increase somewhat.

6.1.2 Direct Digitization of Paper Maps

Paper maps or other imagery may be digitized for storage by using a scanner or digitizing camera. Optical disks using this method of data collection are referred to in this report as "digitized" disks. The digitizing is done by sampling the color and intensity of each definable small area of the image (pixel, or picture element) and assigning a pseudo color and intensity to it. These color and intensity values then form an array of numbers that may be stored on conventional magnetic disks or other media.

An advantage of the above method over using images from a videodisk is the ability to do "rubber sheeting" to remove distortions and piece the maps together. In "rubber sheeting" several lat/lon points near the corners of each image are compared with the equivalent geographic positions on the adjacent image, and the adjoining maps are computationally "stretched" to fit. Another advantage of digitizing maps compared with digitizing videodisk frames is that the number of pixels per inch of map can be chosen to match the stored image with the printer to be used for hardcopy output. Rasterization, the matching of an image's pixel positions with the dot positions of the printer, will then be very simple, and the printed copy will be as clear as possible given the resolution of the stored image.

The amount of data in an image is potentially very large if each pixel is recorded as a separate entity. Thus, optical disks, which can store large amounts of information, are often used. The minimum amount of data required to accurately reproduce the image is considerably less than that used to represent each individual pixel, since most images are largely background color that is fairly constant. Software techniques that add a new data point only when there is a change in the value can be used to compress this information with no loss of information content. The fewer computations needed with compressed data can greatly increase the image processing speed.

The penalties for the "digitized" approach are that the paper maps must be scanned, the images must be "rubber-sheeted", the data must be stored on a relatively expensive write-once-read-many (WORM) optical disk and new indexing software must be written to retrieve the data. WORM drives cost approximately $10K as opposed to $2K for a read-only drive. The media costs roughly $300 per 12 inch disk versus $10 for the read only disk.

6.1.3 Digital Disks Derived From Digitally-Stored Data

As defined here, a digital disk is one that is made from a digital/graphics data base. The digital disk's data base is not made by scanning an image, but may be made by tracing features from an image, or by directly collecting digital data such as by scanning terrain with a radar altimeter. A digital disk may be produced with different features stored separately so that the resulting map has only the needed features without the clutter, and different types of maps may be produced by combining elements of the data base. Overlapping lines, such as common borders that separate two countries, do not have to be stored separately. The data storage can be minimized by storing just one of the overlapping lines, although recreating the feature separates becomes more difficult.

The lines forming the image can be stored in the form of vectors rather than as individual pixels or small groups of pixels. Vectors can combine large groups of pixels into single quantities and the images are processed and transferred faster. The relative lack of detail in a vector rather than raster map is a disadvantage to be weighed against the lack of clutter.

The Defense Mapping Agency is developing a set of digital data bases that may be combined in several ways to produce many types of mapping, charting and geodesy (MC&G) products. The MC&G product set is not due to be fully operational until 1992, so DMA's short term efforts are pointed toward supplying more conventional map products. In the future, deployable data bases will be used to produce the desired end products at the site as well as having conventional paper maps produced at DMA. The complete data base will contain about one million gigabytes of data.

Standardization of the data bases content, format, media, etc. will be a key element in their use. DMA is working with contractors to determine how much information about the topography and natural and man-made features is enough to support emerging weapons and systems. DMA intends to establish close and continuing relationships with weapons and systems developers, labs and users,to ensure DMA is involved early enough in the development cycle to support full scale MC&G development. There are no DMA digital pruducts available currently and standards for their implementation have not been established.

6.1.4 Map Disk Availability

Of the several types of disks that may be used to store the maps, one type of map disk, the Laserdisc, is the only one available that has been produced in an organized, controlled manner, with the maps of interest. Other optical disks using digitized data are available on an ad hoc basis with no overall standard and no source of disks with certified accuracy. The production of DMA's digitized optical map disks could take several years to accomplish, but there are some advantages to the digitized disks mentioned above, for future uses. Laserdiscs available from DMA, Perceptronics and Interactive Television Company (ITC) are listed in Appendix A (**Available Analog Map disks**).

6.2 ANALYSIS OF DISK DRIVE OPTIONS

One objective of this study was to evaluate commercially available disk drives. The results of this portion of the study are presented in this section.

As we have been discussing, disk types may be divided into those storing analog video information and those storing data in a digital format. Digital disk drives may be either optical or magnetic. The optical drives are discussed in this section; however, the reader should be aware of a few facts about magnetic disks. The capacity of magnetic disks has increased to the point that 760 MB devices are available in the standard 5 1/4 inch format used by the MicroVAX II so the capacity is equivalent to that of a small optical disk.

Magnetic disks have the advantages of higher speed in getting to any particular piece of information (26 mS average access time versus 150 mS for an optical disk) and erasability for direct addition of map updates. The transfer rates of standard magnetic and optical disks are comparable. The transfer rate of the disk is more important than the

average access time for retrieval of images, since each image contains a large amount of data and more time is taken in transferral than in access.

The disadvantage of magnetic disks of this capacity is that the media is not removable. Emulex and Trimarchi market modular case systems that enable the entire drive to be removed. Two drives, mounted in modular cases, plug into a standard 19" chassis rack. With this system the drives would have to be mounted outside the MicroVAX II cabinet. The data could be transported on another media, such as tape, but writing, reading and transportation of the media would be cumbersome. For example, a MicroVAX TK50 tape cartridge holds 95 MB (The new 296 MB TK70 streaming tape drive designed for the MicroVAX 3500 may be available for the MicroVAX II at a later date). For a total of 760 MB, eight TK50 cartridges would have to be used for transportation or for storage of classified information.

Appendix B is a summary of a study of optical disks that was done by Rome Air Development Center (RADC). The RADC study compares optical disks and various forms of magnetic storage. The study concludes that optical disks cost less per bit of storage than magnetic storage devices and are capable of high memory capacity and high data transfer rates.

6.2.1 Analog Video Disk Drives

The most common of the analog disk drives is the 12 inch Laserdisc used commercially for television movies and interactive instruction delivery, and in the military for the DMA map disks. Another type of analog disk drive, Laserfilm, can be used for large volume production of videodisks.

6.2.1.1 Laserdisc

The Laserdisc drives of choice are the Sony LDP-2000/1 and the Pioneer LD-V6000. The commercial drives each cost about $2K. Each disk will store 54,000 television resolution images. The differences between the machines are minor, but the Sony LDP-2000/1 is recommended for non-tempest applications due to the overall high-reliability record of Sony products. The Pioneer is available in a tempest version from Atlantic Research for $5.2K (the SG-5120B). It is recommended for tempest applications. Delivery time for the SG-5120B is 60-90 days after receipt of order. Atlantic Research will quote on a tempest version of the LDP-2000/1 or any other device as long as the quantities are greater than 100, so the drive can always be changed when large quantities are needed. Development and certification time for a new Tempest device may be 3-6 months and costs roughly $100K.

6.2.1.2 Laserfilm

McDonnell Douglas Electronics Co. has an analog optical disk product called Laserfilm. It is a method and system for putting Laserdisc information on a low cost photographic transparency film media. The Laserfilm is then read using a player somewhat similar to a standard Laserdisk player. The cost of the mastering and reproduction system is $765K, but the cost of individual film disks is around $5. The

resolution of the present system is about 400x300 pixels and 32,000 images of that resolution can be stored on each disk. The Laserfilm player works well considering the low resolution image. The resolution could be raised, but there is no advantage over the presently available DMA Laserdisks. Laserfilm's advantage for high volume disk replication is not needed for this application.

6.2.2 Digital Optical Disk Drives

Available drives for this application include WORM and CDROM types. Of the WORM drives, 5 and 12 inch diameter disk drives are available.

6.2.2.1 Optimem 1000

The Optimem 1000 12 inch WORM drive has a single-sided 1GB and a 2 GB double-sided disk that have a hard sector size of 1024 bytes. Average access time is 150 mS. Emulex markets the drive and MicroVAX II interface hardware as their L0410/MV-1 subsystem for $12,925 (GSA). The VMS driver and diagnostic software is $3K (GSA)

6.2.2.2 Optical Storage International Laserdrive 1200

Optical Storage International's LaserDrive 1200 stores 1 GB on single sided media and 2 GB on a double sided disk using WORM technology. The hard sector size is 1024 bytes. Average access time is 150 mS. OSI is a joint venture between Control Data Corporation and N.V. Philips, and Control Data markets the drive. Emulex markets the drive and MicroVAX II interface hardware as their L0412/MV-1 subsystem for $13,364 (GSA). Emulex's VMS driver and diagnostic software is $3K (GSA).

6.2.2.3 CDROM - DeLorme Mapping Systems

The DeLorme World Atlas is on a CDROM with a capacity of 550 MB. Their present disk contains maps of about 20 miles to the inch for most of the world. A few sample areas are mapped to one inch per 400 feet. Their software permits 16 levels of zoom, and each level down halves the scale. If the detailed scale maps needed for a particular area of interest were recorded on the disk, the smallest scale would display an area of the world one-half mile square.

DeLorme Mapping Systems has their CDROM-based World Atlas running on an AST Systems PC-AT clone. The bundled system and software costs $25K. The software currently runs under DOS, but DeLorme may have software that runs under UNIX in a few months. The world Atlas is geared toward vector data storage, but they do have provision for some raster imagery similar to what would be seen in a photograph or conventional map. Vector images require relatively small storage capacities, so they are able to get a large number of areas on a CDROM. The vector maps currently stored generally do not show much detail and many areas of interest would have to be digitized for the Atlas to be useful for this application.

6.2.2.4 Optotech 5984

The Optotech 5984 is a 5 inch WORM disk drive using double sided media with a capacity of 400 MB total. The disk must be turned over to read the opposite side. The drive is used with seperate SCSI (Small Computer System Interconnect) or PC interfaces. The sector size is 512 bytes, which is convenient to address since it is the same as the block size used by the MicroVAX's VMS operating system. Average access time is 195 mS. The drive and SCSI interface costs $4500 and double-sided disks cost $125 each. It is an older design than the Maxtor drive listed below and is not recommended due to its smaller capacity.

The Optofile Jukebox which stores 26 GB on 5 inch disks for under $10K should be available in the near future.

6.2.2.5 Maxtor RXT-800S

The Maxtor RXT-800S is a 5 inch WORM disk drive using double-sided media with a capacity of 800 MB total. The disk must be turned over to read the opposite side. The drive contains an imbedded SCSI interface. The sector size is 2048 bytes, so considerable disk space can be lost in bad sectors or ones with data that must be changed, since the whole sector must be rewritten if an uncorrectable error is found. Maxtor guarantees at least 195,310 user-available sectors (400 MB) per side. Average access time is 168 mS. The drive costs $2620 and double-sided disks cost $125 each. This drive has almost half the capacity of the 12 inch disks and is small and inexpensive per bit. Emulex is working with Maxtor to interface the drive to Emulex's MicroVAX-compatable controller.

6.3 COLOR HARDCOPY CAPABILITIES AND LIMITATIONS

Types of copiers, methods for enhancement of the print quality, copier interfaces and subjective evaluation of the combined effects of the various factors are discussed in this section. Most of the copiers were evaluated with an RGB interface to the computer. The advantages and disadvantages of other interfaces, such as Centronics or Versatec types, are discussed in this section too.

6.3.1 Hardcopy Resolution

A printer's "dot pitch", or number of dots per inch, that the printer is made for, will determine the printed size of a stored image residing in a computer's memory. For example, a background map image digitized at 150 ppi will be printed by a 300 dpi printer at half scale unless each pixel in the image is replicated x 2 in the horizontal and vertical directions. The full scale print still has 150 ppi background map resolution although the printer's 300 dpi resolution can be used to display graphics overlays with a finer dot pitch than the background map contains.

When a video image is digitized in a frame grabber such as the Parallax 1280, the digitized image will contain 640x480 pixels, so at a FOV of 3x2 inches, the image will be digitized at a resolution of 213x240 pixels per inch (or half of this resolution for a 6 inch FOV). The finest lines may be slightly blurred since the image has not been sampled at

the Nyquist frequency of twice the resolution, but this is a minor imperfection for this application.

A CMF page is about 8x5 inches and the hardcopy output map should be printed at the same scale as the original paper map. The following is a discussion of the scaling necessary to print a map at true scale from videodisk images combined in a 1280x1024 pixel videographic processor similar to the Parallax 1280. It concludes with the hardcopy resolution resulting after the image is scaled.

A screen 1280 pixels wide contains the equivalent of two 640 pixel 3 inch FOV non-overlapping map images in the 1280 pixel direction (the images overlap as shown in Figure 6.1.1.2-1 so more than two images are used to form the mosaic). If a 300 dpi printer is used, the entire screen of 1280 pixels in width will occupy 4.26 inches at x1 magnification as shown in Figure 6.3.1-1.

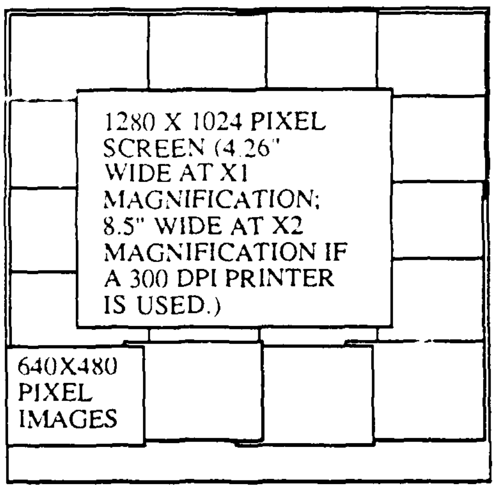


Figure 6.3.1-1 Video Mosaic With X1 Or X2 Scaling

This has to be expanded to the original six inches to obtain true scale. The printers or printer interfaces will expand the screen image by 1, 2, 3 or 4 times. Therefore, if x 2 is used, the picture must be "squeezed" by the image processor so that the hardcopy comes out at true scale. The picture must be squeezed to 0.7 of the size it originally occupied in the image processor's memory (6 inches / 4.26 inches x2 = 0.7), as shown in Figure 6.3.1-2. The maximum printed resolution is therefore increased by the image processor's "squeeze" and reduced by the printer's magnification, to 151x171 dpi. The effective resolution will be close to 150x150 dpi since no attempt has been made to allocate the image's pixel positions with those of the printer (see Rasterization, Section 6.3.2.1). A background map resolution of 150 dpi is acceptable for this application. The image processor for this class of operations (a Parallax 1280) costs about $9K as opposed to less than $3K for a non-digitizing video/graphics overlay processor.

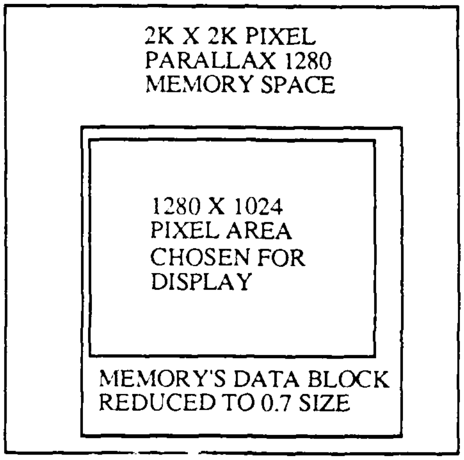


Figure 6.3.1-2 Image Squeeze and Display

6.3.2 Improving The Copy Quality

The image being sent to the RGB graphics monitor may be sent to the copier and printed directly, or the full capabilities of the copier may be exploited by enhancing the image in software. The software may reside on the computer, in a printer interface, or in the printer. The intensity of colors normally produced by combining ink dots of several colors can be improved by adding a special color ink instead of using the combination. Techniques for improving the quality of an image, without raising the resolution, are rasterization, dithering and use of additional ink colors.

6.3.2.1 Rasterization

The clarity of an image printed on a hardcopy output device does not have to be limited by the resolution of the image sent to the video monitor. If a higher resolution image is stored in the computer, that image may be matched to the array of dot locations that the copier is capable of printing, and if that array is larger than the array of pixels the monitor could display, the printed output will be of higher resolution than the screen display.

The process of matching the stored image to the possible pixel locations of the printer is called rasterization. For example, if the desired printed image was to be 12x10 inches (roughly "B" size) and the printer's resolution was 300 dpi, the printer could print 3600x3000 dots on the paper. This is roughly three times the resolution of most high resolution monitors. The print will generally not look as good as an equivalent resolution displayed on a monitor because of factors such as dot size, background color and dot positioning accuracy, but the print can be improved over a copied screen image. Of course, if the background image was only digitized to a resolution of 150 ppi, there would be only 1800x1500 meaningful data points in the background (12" x 150 ppi = 1800 dots).

The disadvantages of rasterization are speed reduction and cost. To decide the color of a 3600x3000 array of dots takes potentially tens of millions of computations. If the computations are done in the host computer, tens of seconds can be taken to rasterize each image. The computation time may be operationally unacceptable. An external rasterizer such as the Versatec RPM can be used to offload the computer and generally costs more than $20K depending on the speed and memory capacity of the rasterizer.

6.3.2.2 Dithering

If a 640x480 pixel image was to be printed on a 200 dpi printer at one dot pre pixel, the hardcopy size would be 3.2x2.4 inches. The image may be enlarged to 12.8x9.6 inches by replicating each dot four times in each direction. This would result in a "blotchy" print that may look worse than the small one. One method of reducing the blotchiness would be to computationally blend the colors of the replicated dot locations between the original image's pixels. This is called dithering, and some copiers automatically use it when producing an enlarged copy. Dithering can greatly improve the apparent resolution and readability of a print.

6.3.2.3 Number Of Ink Colors

Three basic colors (yellow, magenta and cyan) are overlayed to produce all of the colors in the final print. A black dot results when all three colors are overlayed in equal proportions. With a high resolution copier, the dot positions have to be located very accurately and remain accurate over long periods and enviornmental extremes for all three colors to be overlayed exactly on top of the other at any location on the print. If the colors do not "converge" exactly, or if the ink colors vary, the black areas will often be affected most since it takes all three colors to make black. These areas will show variations in color. Black, being used for lettering and radar predictions, is an important color for this application. Some copiers use, or have the option to use, a black ink as well. This not only eliminates most of the convergence concerns, but can triple the printing speed for monochrome prints. The extra thirty percent of time needed to print a four-color versus a three-color copy can be eliminated if the copier can be set to operate in either mode (usually by exchanging four-color and three-color ink rolls in a thermal transfer printer).

6.3.3 Subjective Evaluations

The many variables, in addition to the ones already mentioned, include color intensities of the inks, matte or shiny finish, dot size and placement accuracy. One of the best methods of final evaluation, after knowing the limitations of each technology and being aware of what to look for, is a subjective look at the copy of each device when printing the desired type of material. Then the cumulative effects of the variables can be judged.

Examples of different resolutions and types of copiers are given in Section 6.4. The lowest resolution shown is of a 154 dot-per-inch (dpi) ink jet copier being driven from a 640x480 pixel source. It can be seen that 154 dpi seems to be inadequate and 200 dpi is adequate to display low or medium resolution images. As the copier's resolution is raised to 300 dpi, the copy quality improves, but the example of 400 dpi copy does not appear significantly improved over the 300 dpi print to warrant much additional expense.

6.3.4 <u>Interfaces</u>

A high resolution video image contains a large number of pixels. If it is not sent to the printer in compressed form, such as vectors, it must be sent over a high speed interface. Several interface standards, such as RGB, Versatec and Centronics, are commonly specified for copiers or printers and are illustrated in Figure 6.3.4-1. Video interfaces are high in speed. Interfaces such as Versatec and Centronics are higher in speed than RS-232, but still may take 20 to 40 seconds to transfer a high resolution image.

"Copiers" replicate the image shown on a video screen by connecting the copier to the signals that drive the monitor. "Printers" are driven by a digital data source such as a Centronics or Versatec interface. The data source may be a digital computer or an interface box, such as the Graftel VP 240, that converts a video source to the printer's digital input format in less than 10 seconds. The words "printer" and "copier" are used interchangeably in this discussion, but the types of device interfaces are indicated. As is noted in Sections 6.3.2.1. and 6.4.3.1, the interface may also be used to get a better copy than the screen image, or to free the computer while the printer is making copies.

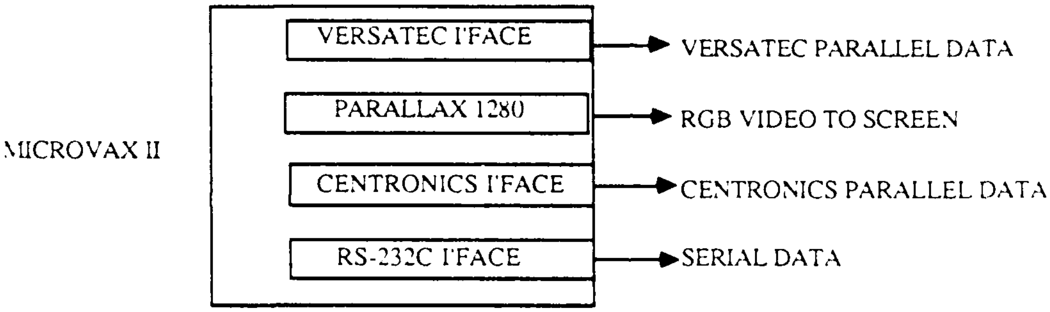


Figure 6.3.4-1 Possible MicroVAX II Interfaces To Be Used For Hardcopy Output

6.3.5 <u>Types of Copiers</u>

Copiers for this application are primarily of the thermal transfer or ink jet variety, although electrostatic printers are also available. Color laser printers such as are now becoming available from IBM and Ricoh cost over $50K and their reliability has not been established.

6.3.5.1 Thermal Transfer

Thermal transfer copiers apply a colored wax coating from a plastic sheet onto a paper sheet by pressing the sheets together and spot-heating them. The used plastic sheets contain a negative image of the one printed so they must be controlled as are classified typewriter ribbons. A printing roll will make from 100 to 300 copies depending on the copy size selected. At least three colors, and sometimes a fourth for black, are used so the paper makes at least three passes through the machine to make a

copy. The process generally takes 30-60 seconds, but in some copiers the image may be stored so the workstation's computer is freed to perform other tasks while copies are being made. Some copiers can store several images and make several copies of each while the computer is being used for other tasks. Since the melting point for the wax is 63 degrees C to 72 degrees C, so the inks could conceivably smear at high temperatures. The hardcopy has been tested at 0 degrees C and the ink showed no damage. The copiers are reliable, do not require leveling as do plotters and are not subject to ink jet clogging.

6.3.5.2 Ink Jet

Ink jet copiers squirt minute quantities of ink from several jets to form the image as the paper and jets are moved. There is no negative image to be disposed of. Modern ink jet printers are less suseptable to jet clogging than their predecessors due to advances in ink formulations and use of continuous circulation of cleaning products. They are still not as rugged or reliable as thermal transfer devices, especially after being unused for a few days.

6.3.5.3 Electrostatic

With an electrostatic printer there are no classified ink sheets to be controlled. A programmed voltage is used to selectively create minute electrostatic dots on the paper to be printed. The paper is then exposed to a colored liquid toner. Multiple passes are generally made to print all the colors. The reliability is estimated to be somewhat less than that of a "Xerox" type copier since it has multiple colors and makes three or four passes per copy.

6.4 ANALYSIS OF COLOR HARDCOPY OPTIONS

Examples of different resolutions and types of copiers are discussed in this section. The many different combinations of image source and copier resolutions, printing methods and types of features to be printed make it imperative to compare many examples. The examples serve to separate the resolution requirements of the image source and printer and to show the minimum image source and printer resolution that is adequate for the application.

6.4.1 Tektronix 4692 Driven By A High Resolution Source

In Figure 6.4.1-1, a 154 dpi copier is being driven by a 1280x1024 pixel graphics source (a Tektronix 4125). Many of the solid lines are jagged or blurred and some have become dotted. Compare this print with Figure 6.4.3.2.3-1 which is similar in size, but printed on a 300 dpi printer. It is also harder to distinguish the fine features in the upper left of the image than it is in Figure 6.4.3.2.3-1. The copy is marginal or unacceptable even though the printer is driven by a high resolution source.

6.4.2 Seiko CH5312

Examples of low and medium-high resolution hardcopy are included in Figures 6.4.2-1 and 6.4.2-2. The copier is a Seiko 5312 203x203 dot-per-inch (dpi) thermal transfer copier that is available in a TEMPEST version for $19.5K from Atlantic

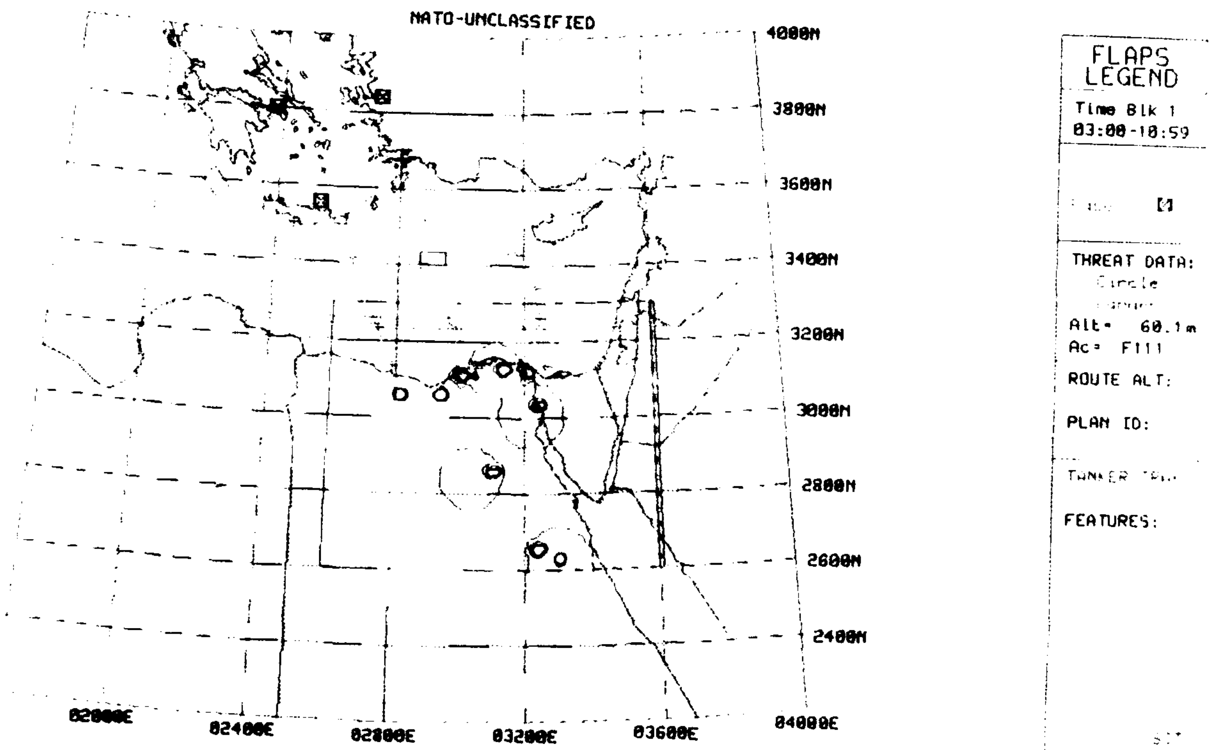


Figure 6.4.1-1 Tektronix 4692 Driven By A High Resolution Source

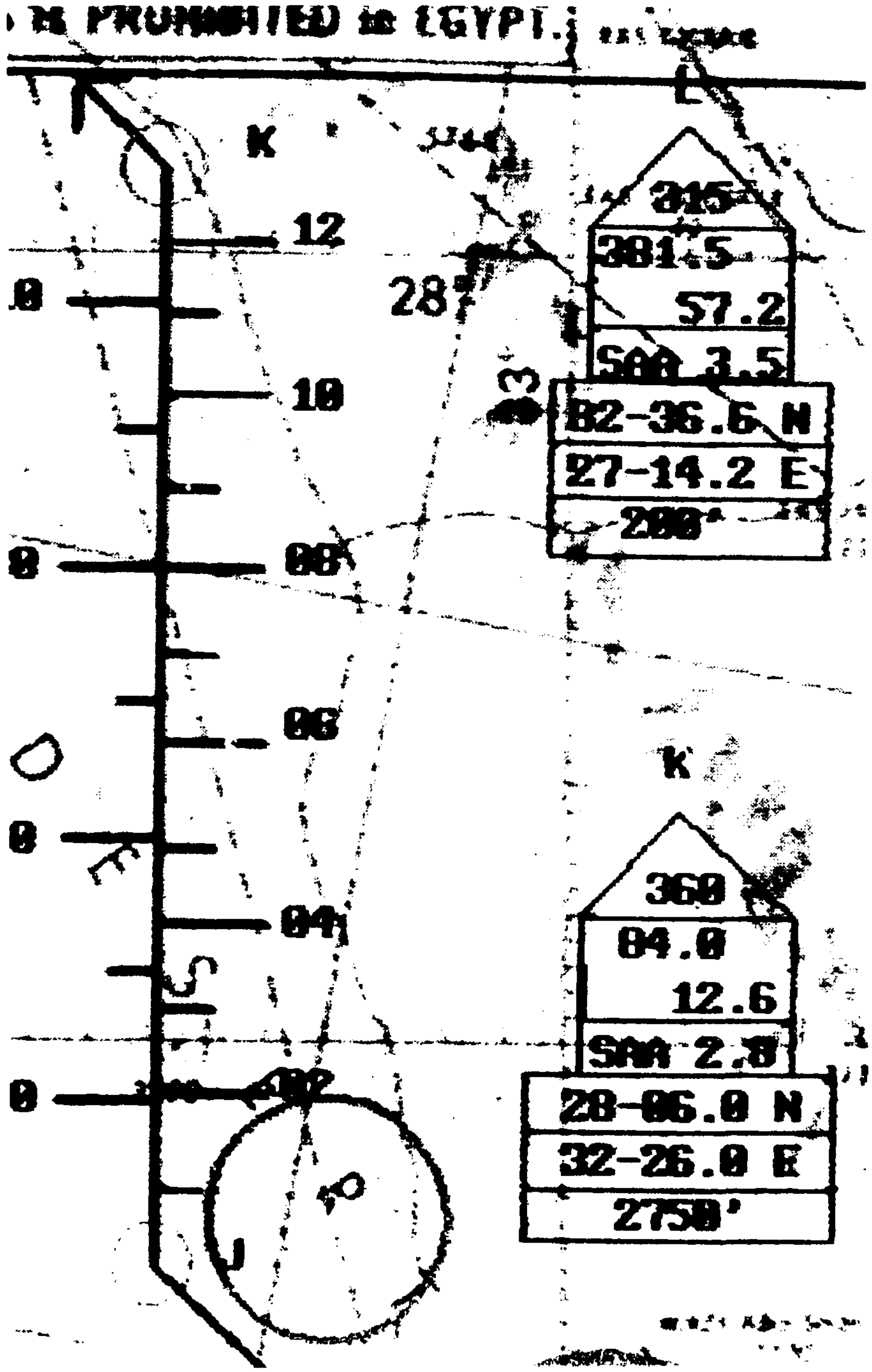


Figure 6.4.2-1 Seiko CH5312 Driven By A Low Resolution Source

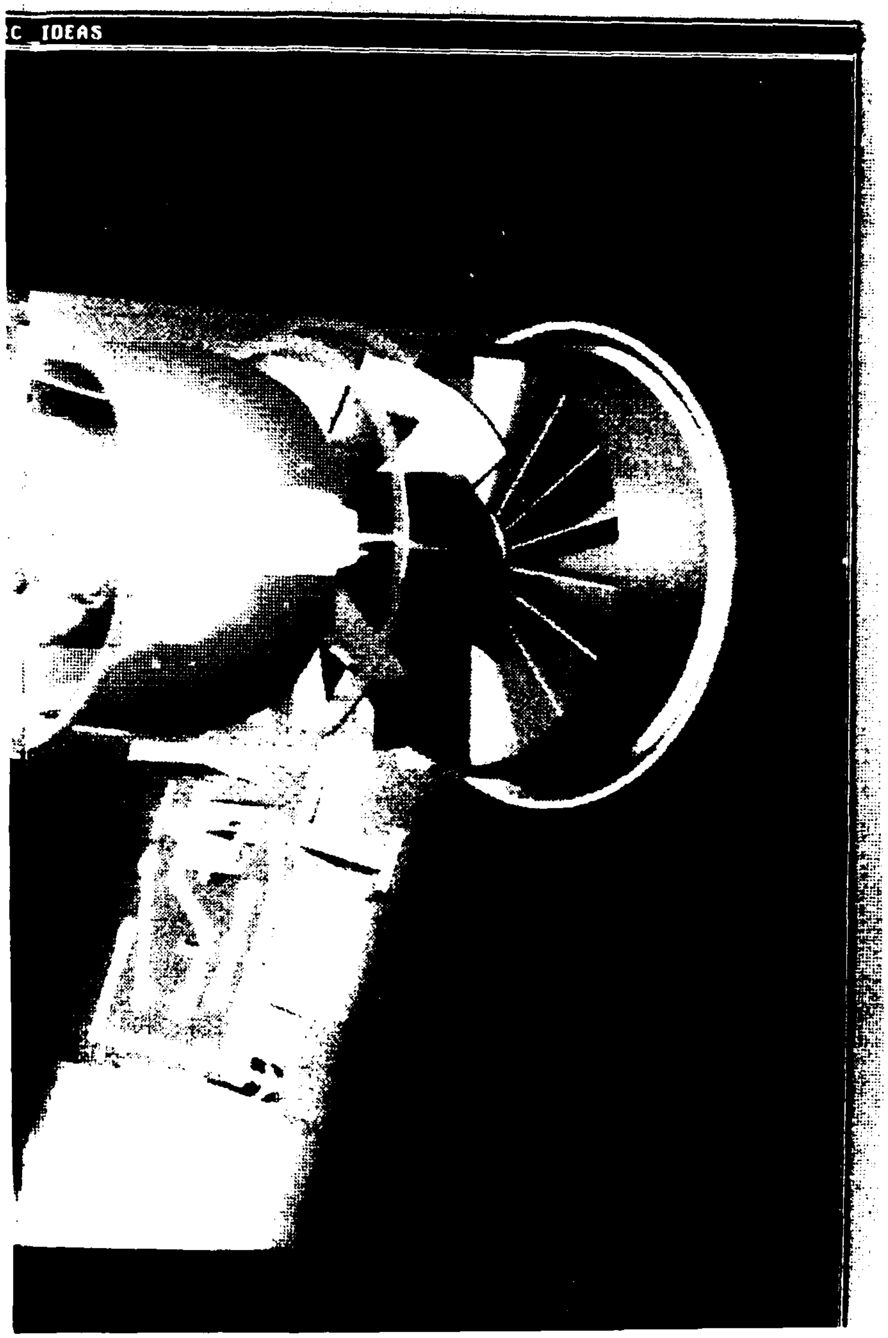


Figure 6.4.2-2 Seiko CH5312 Driven By A Medium-High Resolution Source

Research (Model T5112). The commercial version costs $12K. The 5312 is reliable and easy to use. It can be programmed to enlarge the image by 2 or 4 times and can rotate the image by a set 90 degree rotation. It can make multiple copies of a single image, which is captured in 20 seconds. Since it uses a three color ink sheet, black is not quite as intense as it could be.

6.4.2.1 Seiko CH-5312 Driven By A Low Resolution Source

This copy (Figure 6.4.2-1) shows a typical CMF map image . The 5312 is a 203 dpi thermal transfer printer with an analog RBG input. It is being driven here by a 640x480 pixel source. The contour lines on the map image are somewhat blurred and the lines that are slightly off of horizontal or vertical are jagged. The narrowest lines are fairly wide due to the enlargement of the image. Even at this resolution, the map is quite useable. This is a 4x4 pixel-replicated image. When at this enlargement setting this copier automatically dithers the image (blends the colors of the replicated pixels).

6.4.2.2 Seiko CH-5312 Driven By A Medium-High Resolution Source

For Figure 6.4.2-2, the copier was driven by a MicroVAX II GPX screen with a resolution of 1024x864 pixels. Some things to look for are the clarity of the fine details and the smoothness of the lines that are nearly vertical or horizontal. The lines are less jagged and blurred than those of Figure 6.4.2-1 and the fine lines, like those at the right edge of Figure 6.4.2-2, are much narrower.

6.4.3 Versatec Versacolor And Mitsubishi G650

An alternative to the Seiko CH-5312 is the Versatec Versacolor 300X300 dpi copier. The Versatec Versacolor is apparently internally identical to the Mitsubishi G650 except that the Versacolor can be ordered with a Versatec interface if desired. Also a thermal transfer printer, it produces an 8.5X11 inch print in 45 seconds and an 11X17 inch print in 60 seconds (or a monochrome print in 20 seconds). The Versacolor and G650 copiers have the option of using a four-color ink roll. The fourth color is black and can be used to make faster and more uniform black radar prediction images than a three-color system could. The Versacolor and G650 list for $9K.

6.4.3.1 Interfaces

The Cromemco or Parallax image processors and the Tektronix 4125 terminal have an analog output, called RGB, consisting of cables for the red, green and blue components of the image. Many printers, such as the Versacolor, G650 and Tektronix 4693D use a Centronics interface. A Graftel VP 240 video processor could be used to drive the printers since the VP 240 does the conversion between the two signal formats. Other interfaces are available to convert between a MicroVAX's Q-Bus and Versatec or Centronics formats.

6.4.3.1.1 Graftel VP 240 Video Interface

The VP 240 "captures" a screen image in about 6 seconds, after which multiple copies of each image may be printed. The standard 240 can store six different 640x480 pixel images (or one 1280x1024 pixel image) so the computer isn't slowed down while

copies are being made. This is an important advantage for the operator since it takes about a minute to print each copy and may take an additional 20 to 40 seconds to transfer the image to the printer if a video interface is not used. A memory expansion board is available for the VP 240 so that 6 of the 1280x1024 (or 27 of the 640x480) images can be stored. The VP 240 has an RS-232 interface for setting the screen parameters. The RS-232 interface can not currently be used to set the printing parameters for computer-controlled operation. The front panel push-buttons on the VP 240 must be used to control printing action. Neither the Versacolor or the VP 240 are available in a TEMPEST version, but they can be put in an emission-resistant enclosure. The VP 240 lists for $4.5K.

6.4.3.1.2 MDB Systems MLSI-F-LP11-C Centronics Interface

The MDB MLSI-F-LP11-C converts between a MicroVAX's Q-Bus and Centronics interface formats. It is directly supported under VMS since the MDB interface operates as if a standard line printer was connected to the Q-Bus. The interface does not capture images for "off-line" printing, and rasterization software would have to be written, by the contractor who writes the map manipulation software, to print the images. The MLSI-F-LP11-C interface costs $510.

6.4.3.1.3 Versatec 126

The Versatec 126 interface converts between a MicroVAX's Q-Bus and Versatec parallel formats. It is supported under VMS by using a software driver from Versatec. The interface does not capture images for "off-line" printing. As with the MDB, rasterization software would have to be written, by the contractor who writes the map manipulation software, to print the images. The Versatec 126 interface costs $4K including the driver software.

6.4.3.2 Resolution, Pixel Replication and Rasterization

The following subsections of Section 6.4.3.2 show the effects of low and high resolution image sources, x 2 and x 3 pixel replication, and rasterization on hardcopy produced by the Versacolor/G650 printer.

6.4.3.2.1 Low Resolution Source, 3 x 3 Pixel Replication

In Figure 6.4.3.2.1-1 the Versacolor copier is being driven by a 640x480 pixel source, using a Graftel VP 240 interface. The almost vertical and horizontal lines are not as jagged and the small print is not as blurred as in Figure 6.4.2-1 due to the smaller enlargement. The graphics print is readable, but the small video print is not. Compare this print with Figure 6.4.2-2 where the resolution of the VAXStation II/GPX (1024x864) is roughly equivalent. In Figure 6.4.3.2.1-1 there are 480 pixels of the screen image displayed in the vertical direction and the vertical size of the printed image is 4.8 inches. The video image's field of view is six inches, so the map is being displayed at close to true scale. A 1280x960 screen image could use this same enlargement factor to fill a 9.6x12.8 inch (approximately B Size) print. In other words, a 1280x1024 pixel screen image with a x 3 magnification with a map mosaic background made up of four video images should look similar in resolution to the one described here. Since pixel replication is being used (in the VP 240), the printed image could be clearer if the source resolution was higher. It could be 50% higher if the background map was digitized at 150

Figure 6.4.3.2.1-1 Versacolor, VP240, Low Resolution Source, 3 x 3 Pixel Replication

dpi and no enlargement was used, but at this resolution of 100 dpi the maps are quite useable so the copy is acceptable when the printer is driven by this source. Eight three-inch field-of-view video images could also be used to double the clarity of the background map.

6.4.3.2.2 High Resolution Source, 3 x 3 Pixel Replication

To print Figure 6.4.3.2.2-1 the copier was being driven by a 1280x1024 pixel source, using a Graftel VP 240 interface. Figure 6.4.3.2.2-1 is a graphics image that clearly shows the effects of pixel replication on the almost vertical and horizontal lines. They are jagged since the printer draws a vertical line three pixels wide until the line in the original image moves three pixels horizontally, and then draws another vertical line, and so on.

6.4.3.2.3 High Resolution Source, 2 x 2 Pixel Replication

In Figure 6.4.3.2.3-1 the copier was being driven by a 1280x1024 pixel source as above. Figure 6.4.3.2.3-1 shows the effects of a x 2 pixel replication on the almost vertical and horizontal lines. Compare this print with Figure 6.4.3.2.2-1. The copy is improved as expected when the printer is driven by x 2 pixel replication, but the image is smaller. The lines are not as jagged since the printer draws a vertical line two pixels wide until the line in the original image moves two pixels horizontally, and then draws another vertical line, and so on. The copy could be further improved by rasterization since the pixel locations of the image could be matched to the printer and the fine lines could be made a single pixel wide.

6.4.3.2.4 Mitsubishi G650 Driven By A High Resolution Rasterized Source

This print, Figure 6.4.3.2.4-1 illustrates the ultimate capability of the 300 dpi copier. The rasterizer for this picture was a Gammadata device costing about $10K, and the rasterization could be done in software on the MicroVAX II. The fine details show almost photograph quality on the 300 dpi print.

6.4.4 Tektronix 4693D Driven By A High Resolution Source

The 4693D can be driven directly from the 4692 interface on a Tektronix 4125 terminal. The printer has the x 2 and x 3 scaling capability of the VP 240. Three interface modes can be used by the copier; Centronics, Tektronix 4692 and Tektronix high-speed parallel. Using the Centronics mode, an image capture takes about 40 seconds. By modifying the Centronics command sequence, the 4693D will accept a more efficient "string" of pixels and the transfer time can be reduced to about 20 seconds. It has the capability to capture from one to three images in six seconds per image using the Tektronix high-speed parallel interface. The 4693D's printing can be controlled by a Centronics interface in the computer, so copying can be fully automated. The 4693D costs $8K with 4MB of memory (enough to store one image). The additional memory necessary to store three images costs $4K. Since the maximum printable area is 8.13x10.74 inches per "legal-size" copy, two CMF pages could be printed at once. Figures 6.4.4-1 through 6.4.4-3 show 1K x 1K pixel images expanded by a non-integer multiple to fill the available print area.

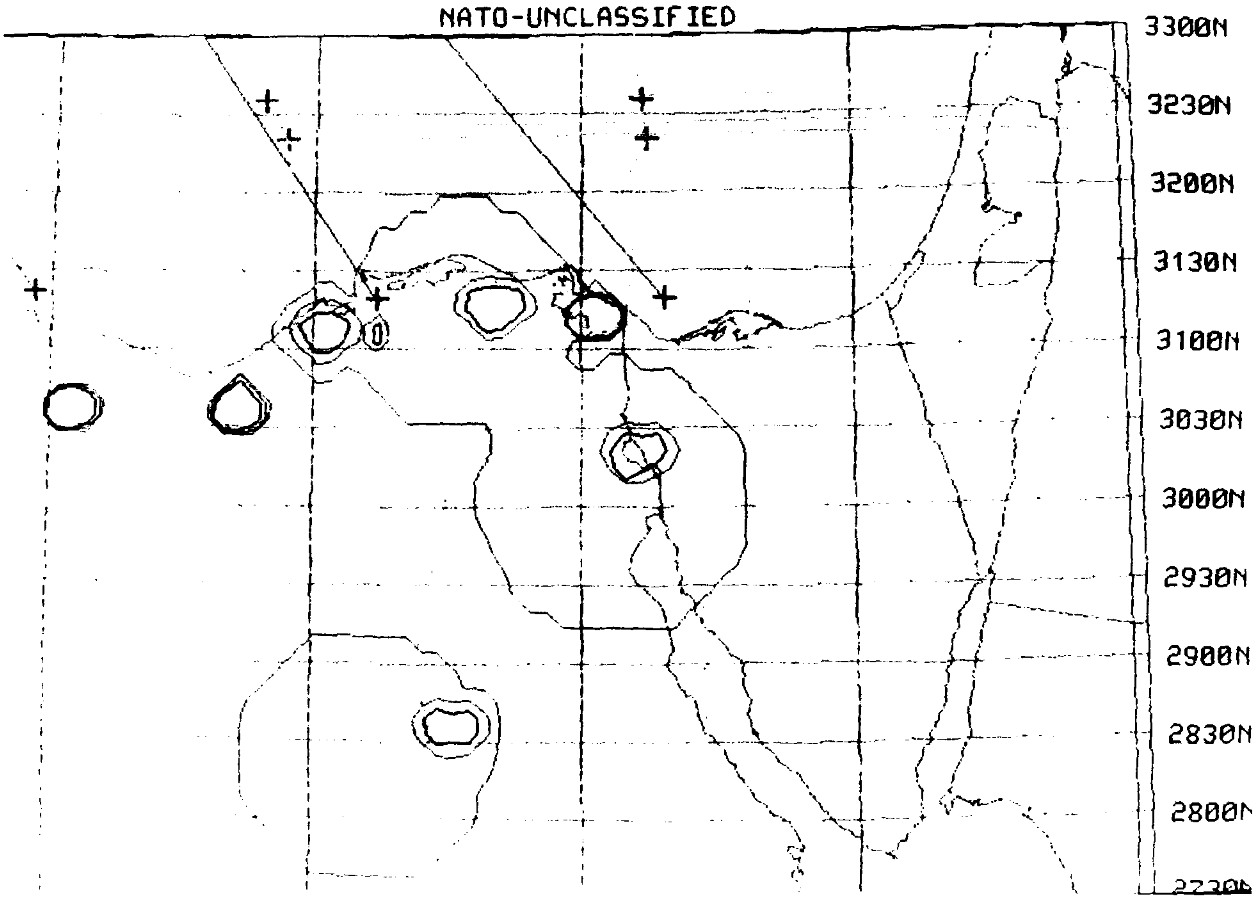


Figure 6.4.3.2.2-1 Versacolor, VP240, High Resolution Source, 3 x 3 Pixel Replication

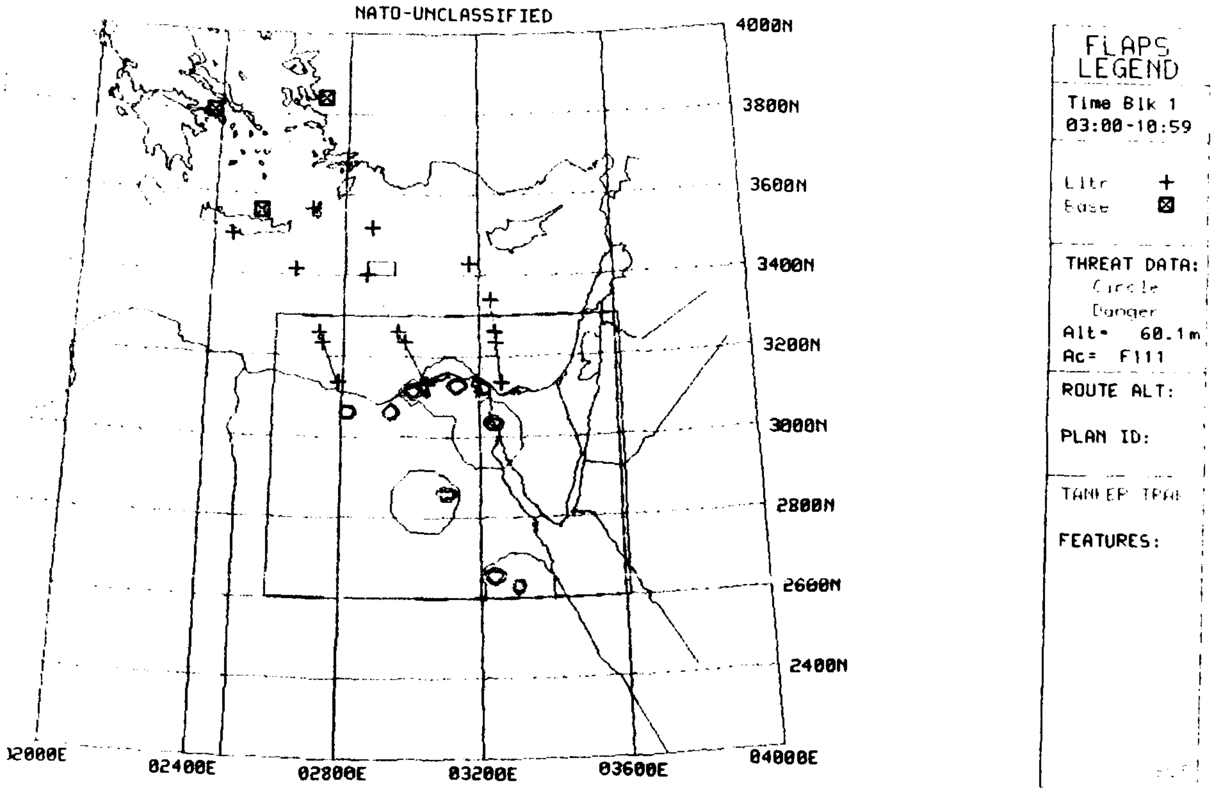


Figure 6.4.3.2.3-1 Versacolor, VP240, High Resolution Source, 2 x 2 Pixel Replication

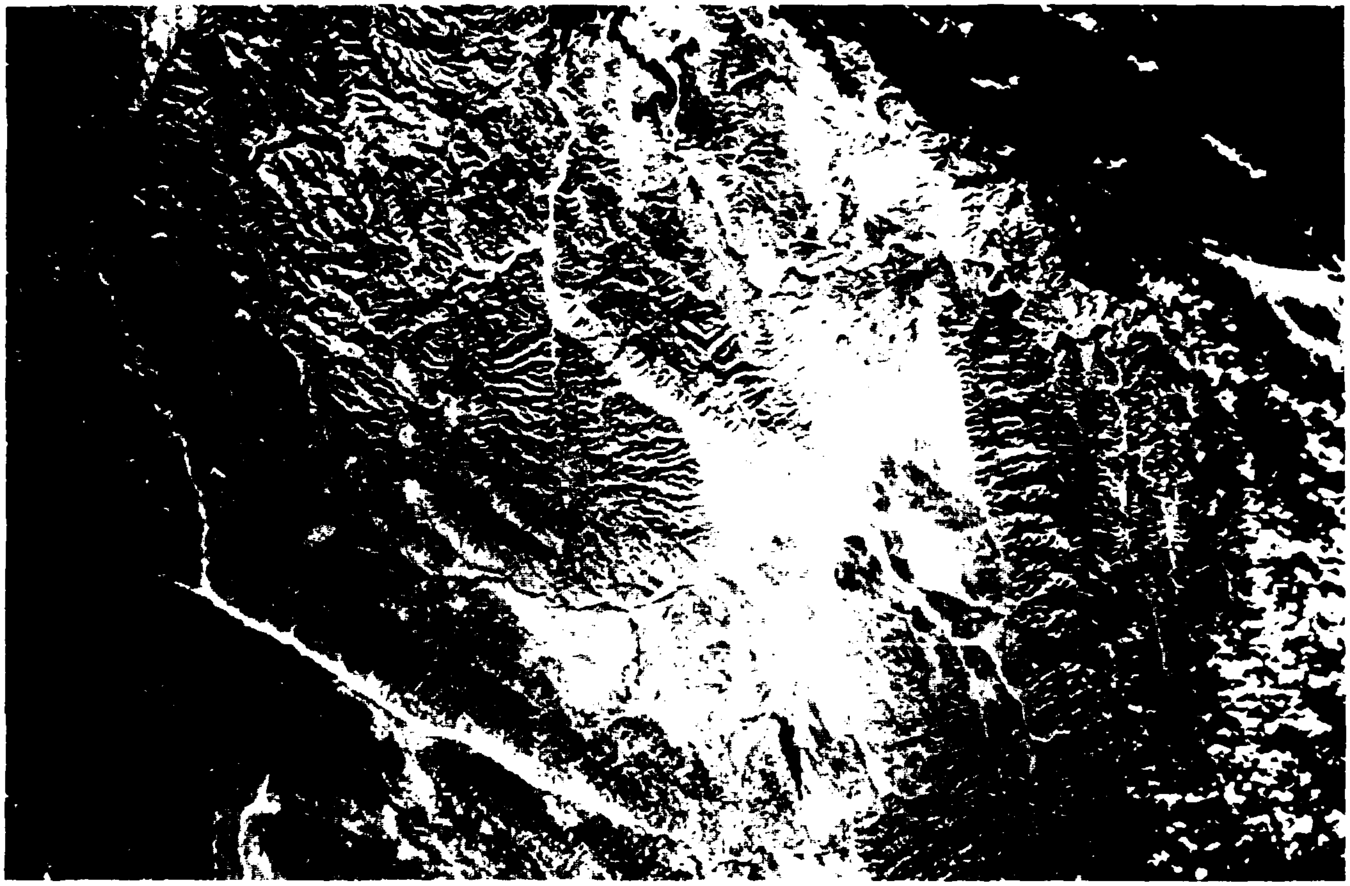


Figure 6.4.3.2.4-1 Mitsubishi G650 Driven By A High Resolution Rasterized Source

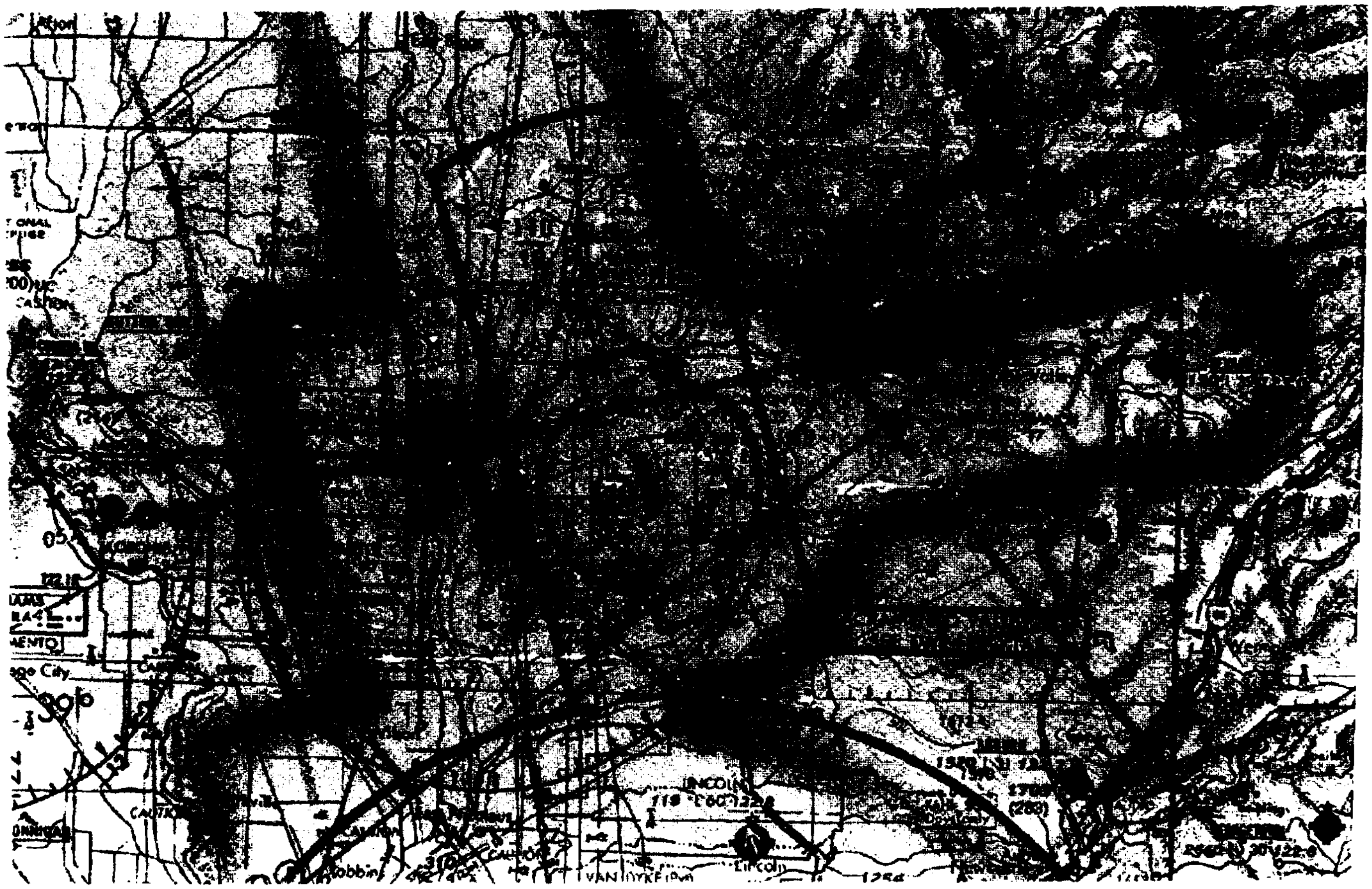


Figure 6.4.4-1 Tektronix 4693D Driven By A High Resolution Source

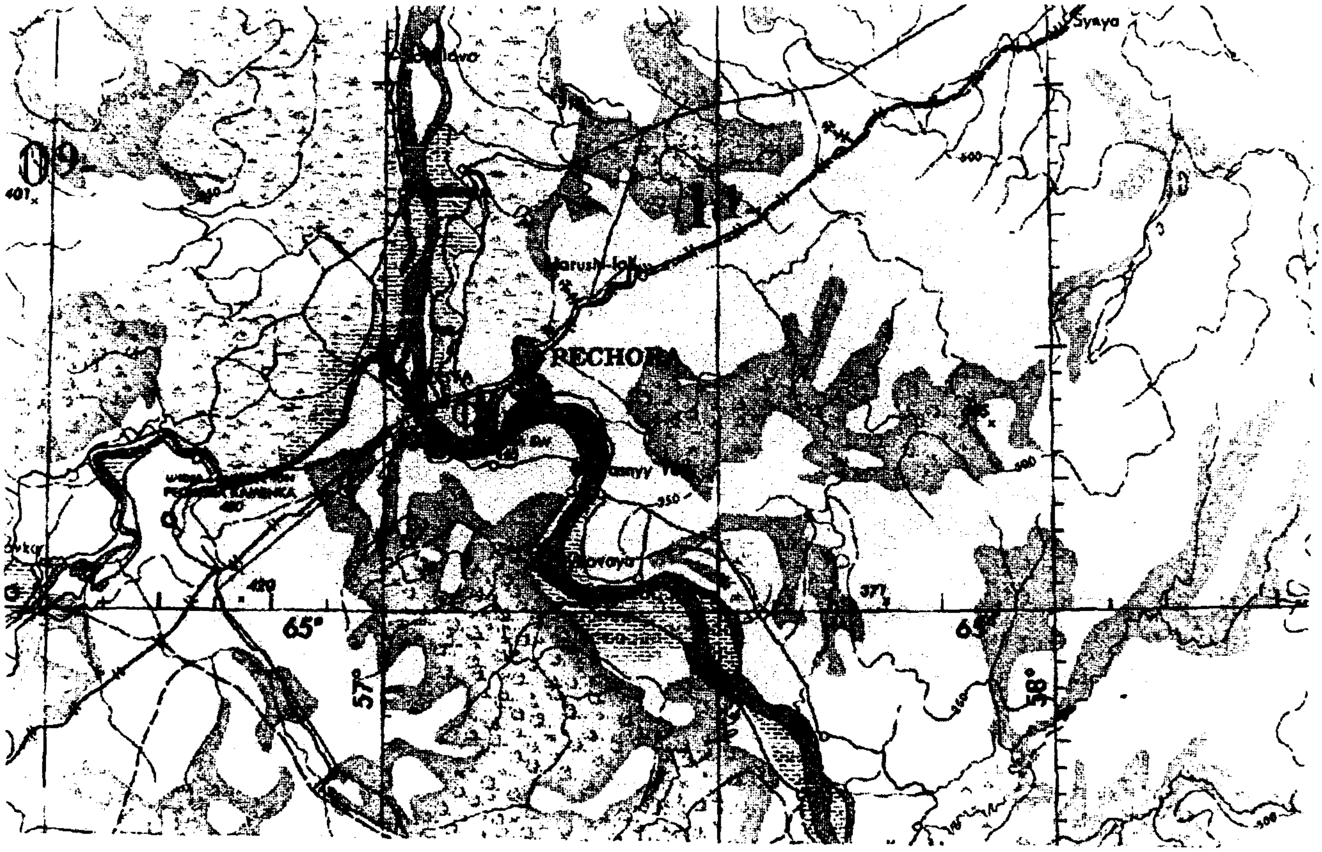


Figure 6.4.4-2 Tektronix 4693D Driven By A High Resolution Source

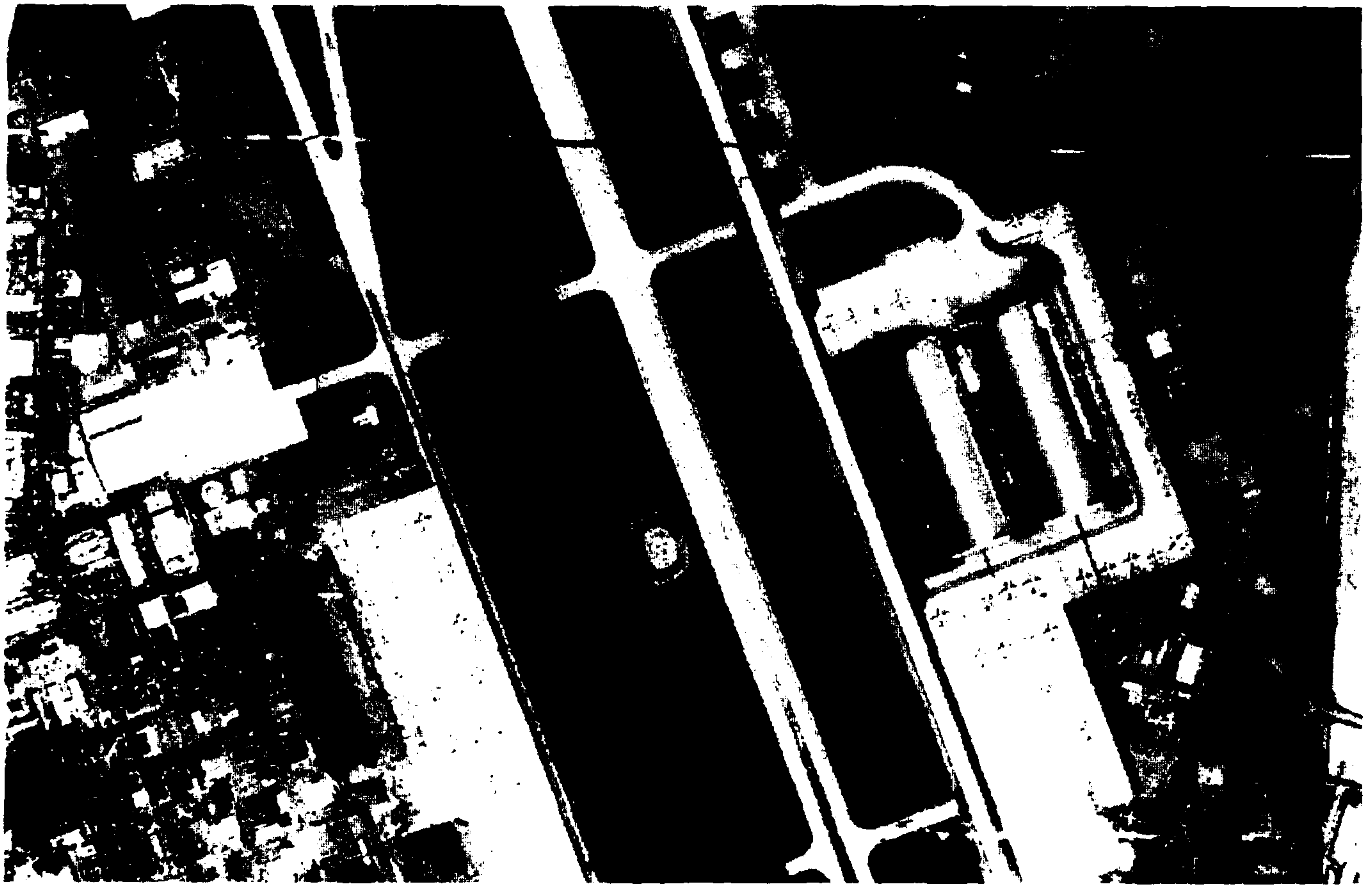


Figure 6.4.4-3 Tektronix 4693D Driven By A High Resolution Source

In general, the images from the 4693D are quite acceptable, but there are some artifacts that require explanation. Figure 6.4.4-1 has a white line extenting across the map about one inch from the top of the map. This was reportedly caused by a dirty print head. Figure 6.4.4-2 has what appear to be registration or scaling errors between the color passes, evident at the lower right corner of the copy. Figure 6.4.4-3 shows a gray-scale print similar to one that would be produced for radar predictions. There is a line of apparently bad data about one inch from the bottom of the copy, going across the runways. The copier is reasonably priced for the capability, but the flaws in the prints reviewed here leave some doubt as to the 4693D's reliability. If the doubts are resolved in the future, the 4693D would be a good printer for this application.

6.4.5 ACMF 400 Dpi Printer Driven By a High Resolution Source

In Figure 6.4.5-1 the Logicon Automated Combat Mission Folder System's 400 dpi printer was being driven by a high resolution image. The almost vertical and horizontal lines are smooth and the small print is clear. Compare this print with Figure 6.4.3.2.1-1 for its video background, 6.4.3.2.4-1 for rasterized map background or Figure 6.4.3.2.3-1 for graphics overlays. The 6.4.4-1 copy is quite acceptable, but not that much better than that shown in the other figures. The advantages of a 400 dpi printer can only be seen if the image source is 400 dpi or better. If the maps were digitized at 150 dpi and were to be printed at true scale, the rasterizer would be able to do no better than if it was driving a 300 dpi printer and replicating every pixel twice. It might even look worse if there were spaces between the printed pixels due to 400 being a non-integral multiple of 150. The only improvement might be with vector graphics where the vectors can be plotted to greater accuracy.

The Versatec Spectrum C2558 400 dpi printer is available for $17K with a Versatec interface board that will fit in a MicroVAX II. The Versatec Spectrum is an electrostatic printer, so there are no classified ink sheets to be controlled. The reliability is estimated at somewhat less than that of a "Xerox" type copier since this has four colors and makes four passes per copy. An A-size color print is made in 75 seconds, monochrome in 5 seconds. A B-size color print is made in 90 seconds, monochrome in 10 seconds.

6.4.6 Conclusions

Section 6.4.6 presents conclusions derived from analyzing video and digitized optical disk technologies, image processors, choices of available disk drives, printers, printer interfaces and software required for the mission planning workstation.

6.4.6.1 Hardware Component Technology Conclusions

Videodisks can be used by a mission planning workstation if they are digitized for processing. Laserdiscs are available from DMA and are sufficient for near-term use with the caveat that there may be slight dislocations between adjoining map images in a mosaic, similar to those found at the joining of conventional paper maps. A fast processor with the capability to rotate and mosaic the images is needed. The Parallax 1280 video/graphics processor is recommended, as are the DMA videodisks.

The distortions between adjacent map images can be reduced more effectively on digitized map disks than on videodisk images, but the videodisk mosaic images should be

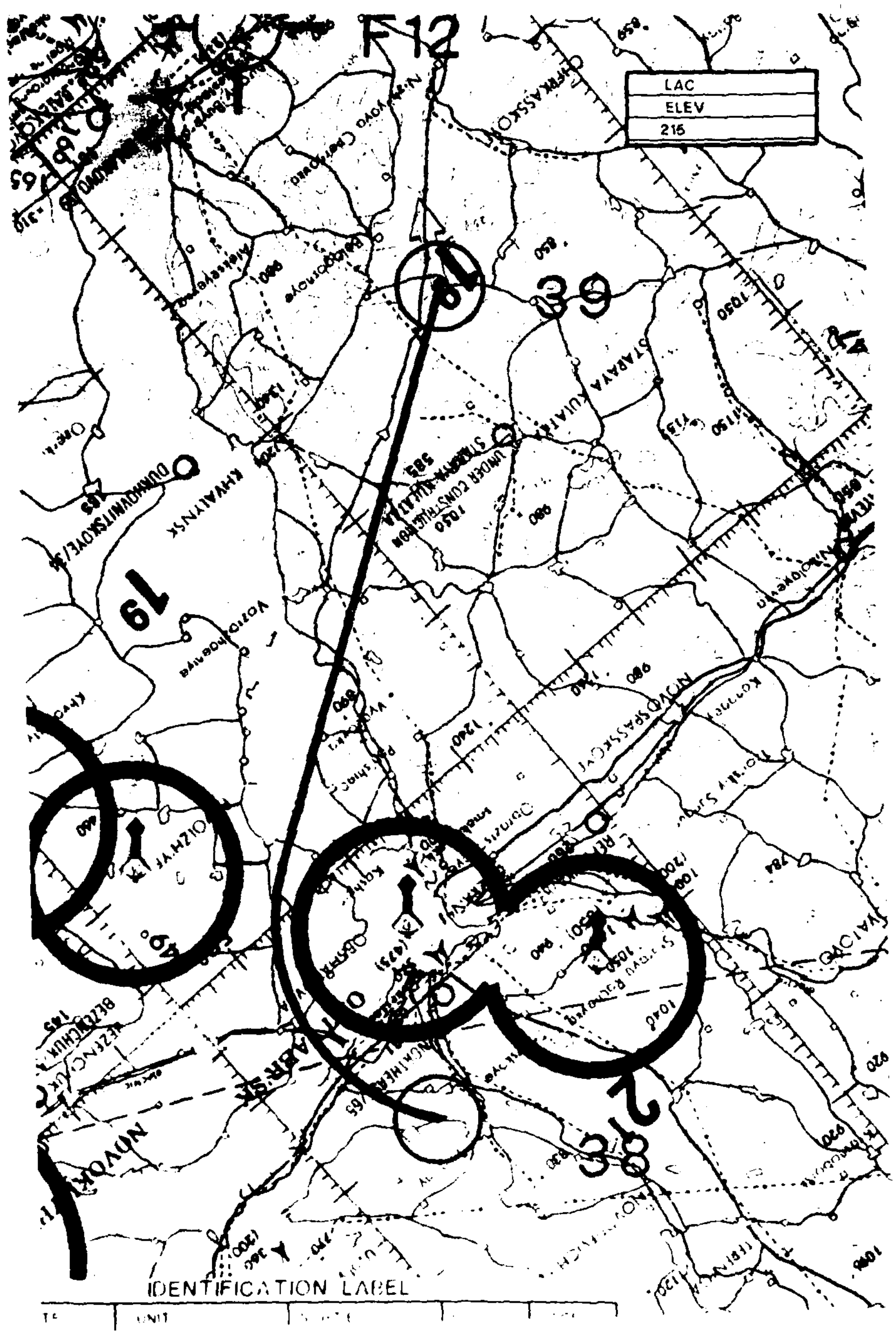


Figure 6.4.5-1 ACMF 400 Dpi Printer Driven By A High Resolution Source

sufficient. The access time for a digital drive (about 150 mS) is faster than for a videodisk drive (about 500 mS), but the digitized or digital map disks are not readily available yet. No source of standardized-format digitized disks with certified accuracy is available, so the videodisks are recommended for this mission planning workstation.

6.4.6.2 Disk Drive Conclusions

If the DMA Laserdiscs are to be used, the Atlantic Research SG-5120 is recommended for tempest systems. For non-tempest applications, the Sony LDP-2000/1 is recommended. Table 6.4.6.2-1 describes the Laserdic options. If pre-recorded disks are not to be used, the choice of a WORM drive is first dependant on the amount of data to be stored. Image digitization at a resolution of 150 pixels per inch and 7 or 8 bits per pixel for color is sufficient for this application. At this rate a 12 inch 2 GB WORM drive will hold 720 square feet of maps. A 5 inch 800 MB WORM drive will hold 260 square feet of maps and is sufficient for tactical uses, especially since the drives are small enough to use two if more storage is needed and the user does not want to change disks. The Maxtor RXT-800S gives the best price/bit of these drives.

6.4.6.3 Copier Technology Conclusions

Thermal transfer printers are more reliable than ink jet printers and are preferable even though the used ink sheets will have to be controlled. Electrostatic printers are a possible alternative to thermal transfer devices if high reliability can be established. Upgrading should be easy if an RGB or Centronics interface is used with the present printer. An RGB interface is considerably faster than a Centronics interface, so RGB is preferred. Color laser printers are too expensive now, but may be a good alternative in the future.

Some copiers have no image capture capability. Since the time taken to print a copy is significant and the Graftel VP 240 RGB interface rapidly stores images and frees the computer for more mission planning while copies are being printed, the interface is very desirable. The VP 240 interface does not require driver or rasterization software. If another interface is desired at a later date, a driver for the interface can be purchased. The rasterization software would have to be written by the contractor who writes the rest of the mission planning workstation's software.

6.4.6.4 Copier Resolution And Type Conclusions

As noted in the requirements section, the hardcopy resolution must be sufficient to show contour lines, but need not be indistinguishable from a standard DMA paper map product. Overlay text must be clearly readable, but fine text on the background map need not be as clear since it will be rotated at an arbitrary angle and can be reproduced on the graphics overlay if needed. A resolution of 150 dots per inch is too low for the graphics overlays, but is sufficient for the background map. The 200 dpi copiers deliver adequate prints for low to medium resolution work, but 300 dpi can produce a near photograph quality image on an 11X17 format when driven by a high resolution rasterized source. Thermal transfer printers are more reliable than ink jet printers, therefore, thermal transfer is preferred. The more limited temperature range of thermal transfer hardcopy versus ink jet hardcopy is not expected to pose operational problems. If the current lack of tempest certification on the printer can be accepted, a Versatec Versacolor or Mitsubishi G650 300 dpi thermal transfer printer would be an excellent device for present and future efforts.

Table 6.4.6.4-1 Hardcopy Options

OPTION #	DESCRIPTION	PROS	CONS	RESOLUTION	IMAGE CAPTURE SPEED, # STORED	COPY SPEED	COST	INTERFACE	RECOMMENDATION
1	SEIKO CH 5312 (THERMAL TRANSFER)	AVAILABLE IN TEMPEST VERSION (ATLANTIC RESEARCH). HAS DITHERING ON X4 ENLARGEMENT FOR SMOOTHER IMAGE. CAN ROTATE IMAGE 90 DEGREES AND RELOCATE ON PAGE. RELIABLE.	HAVE TO REMOVE INK SHEETS FOR DECLASSIFICATION. SHINY IMAGE (WAX)	203 DPI	20 SEC., 1 IMAGE	A SIZE 65 SEC B SIZE 120 SEC	$12K COMMERCIAL, $19.5K TEMPEST	ANALOG RGB	RECOMMENDED FOR LOW RESOLUTION SYSTEM.
2	VERSATEC SPECTRUM ELECTROSTATIC PRINTER/PLOTTER		NEEDS RASTERIZER. MAY BE OVERKILL FOR LOW RES VIDEO. NOT EASY TO INTERFACE TO. LARGE PHYSICAL SIZE. MAY BE LESS RELIABLE THAN THERMAL TRANSFER	400 DPI		A SIZE 75 SEC B SIZE 90 SEC	$30K+ ESTIMATED COMMERCIAL WITH RASTERIZER	VERSATEC PARALLEL	NOT RECOMMENDED (COSTLY, LARGE, FRAGILE, HARD TO TRANSPORT).
3	RICOH COLOR LASER		UNABLE TO GET INFO FROM MANUFACTURER. MAY PRINT A SELECTED SINGLE COLOR ON ENTIRE SHEET.	N/A	N/A	N/A	N/A	N/A	STILL TOO EARLY IN DEVELOPMENT CYCLE. NOT RECOMMENDED.
4	TEKTRONIX 4693 D WITH GRAFTEL VP 240 INTERFACE		POSSIBLE RELIABILITY ISSUES	300 DPI	2-14 SEC., 6 AT 640X480 OR 1 AT 1280X1024 OPTIONS FOR 27 AT 640X480 OR 6 AT 1280X1024	64 SEC	$12.5K	ANALOG RGB	MAY BE RECOMMENDED IN THE FUTURE IF HIGH RELIABILITY RECORD IS ESTABLISHED.
5	VERSATEC VERSA-COLOR WITH GRAFTEL VP 240 INTERFACE	RGB INTERFACE WILL WORK WITH SCREEN RESOLUTIONS TO 1280X1024	NOT TEMPEST CERTIFIED (WILL PROBABLY HAVE TO USE CONTAINMENT)	300 DPI	2-14 SEC., 6 AT 640X480 OR 1 AT 1280X1024 OPTIONS FOR 27 AT 640X480 OR 6 AT 1280X1024	A SIZE 30 SEC B SIZE 60 SEC	$13.5K	ANALOG RGB	HIGHLY RECOMMENDED. TEMPEST CERTIFICATION CAN BE ACHIEVED BY CONTAINMENT.

The Tektronix 4693D is an alternative to the Versatec or Mitsubishi 300 dpi thermal transfer printer, but there is some doubt as to the 4693D's reliability. If the doubts are resolved in the future, the 4693D would be a good printer for this application. A 400 dpi electrostatic printer is available. It has the advantage of having no classified ink sheets to be controlled, but it is expensive and may not be as reliable as the thermal transfer printer. The image source resolution is not high enough for a 400 dpi printer to significantly improve the copy resolution. Rasterization, if needed, can be done in the MicroVAX, if used, and if the printer is driven by a digital rather than video source. Capturing an RGB screen image will not display the full capabilities of the printer and graphics image, but it is sufficient for this application. In addition, the advantages of a relatively device-independent interface such as RGB and capturing the images so they can be printed offline may outweigh the advantages of the additional resolution. The VP 240 RGB interface can be driven by resolutions up to 1280X1024 pixels interlaced or non-interlaced, so it would be useable with low or high resolution sources. Table 6.4.6.4-1 summarizes the hardcopy options.

6.4.6.5 Software Component Technology Review And Conclusions

Software to locate specific information on the disk, operate the optical disk drive, control the video/graphics processor to display the area of interest and overlay the routes and annotations is available for some video/graphics processors, but not for processors with the capabilities of the Parallax 1280. Interactive Television Corp.'s (ITC) Program Development Libraries (PDL) perform the videodisk control and graphics overlay operations, but the PDLs were written for video processors that do not have the required image mosaic or rotation capability. The PDLs are available for the MicroVAX II (using a video processor that is inappropriate for this application), but the portions of the PDLs that are used to operate the videodisk player can be used for this application, and are recommended. Software for control of a Parallax 1280 video/graphics processor should be written by the contractor who writes the bulk of the mission planning system's software. The software for the graphics overlays should be written in a portable or device-independent language such as the Graphical Kernel System (GKS).

No commercially available software exists for indexing and manipulation of digitized disks. Some software has been written by various companies for operation of their workstations, but it is generally not commercially available.

Table 6.4.6.2-1 Laserdisc Options

OPTION #	DESCRIPTION	PROS	CONS	ISSUES	COST	RECOMMENDATION
1	SONY LDP-2000/1	POSSIBLY HIGHER RESOLUTION. VERY GOOD RELIABILITY RECORD ON SONY PRODUCTS. MARTIN MARIETTA HAS A UNIT IN AN ENCLOSURE WITH EMISSIONS SPECIFIED TO MIL STD 461B.	NOT TEMPEST CERTIFIED.	WILL CONTAINMENT OF THE SIGNALS WITHIN THE FACILITY ELIMINATE THE NEED FOR CERTIFICATION?	$2K	USE IF TEMPEST CERTIFICATION ISN'T REQUIRED.
2	PIONEER LD-V6000	AVAILABLE IN TEMPEST VERSION (ATLANTIC RESEARCH SG- 5120)			$2K FOR LD-V6000 $5.2K FOR SG-5120	USE SG-5120 IF NEEDED FOR FOR TEMPEST REQUIREMENTS. SONY LDP-200/1 IS RECOMMENDED OVER PIONEER LD-V6000 BECAUSE OF ITS HIGHER RESOLUTION.

7. PRESENTLY AVAILABLE WORKSTATIONS

Several systems and options are currently available that may be used to provide video map and CMF preparation capabilities. A discussion of each is presented here.

7.1 CROMEMCO BASED MSS

This section discusses use of the present TAC MSS without adding another general purpose computer to the workstation. The MSS uses the Flight Planning System (FPS) and PEN-AIDS software, which are written to drive the Cromemco S-Series graphics boards. It would be desirable from a cost and schedule point of view to stay with a compatible set of hardware and commands for operation of both the present and proposed hardware. The present FPS and PEN-AIDS software interfaces with the Cromemco S-Series graphics using Cromemco's Baseline software. Another constraint is the desirability of keeping as many of the components within the original chassis boxes as possible so as to not add to the "footprint", or present additional portability or reliability issues. Within these hardware and software constraints the Cromemco S-Series graphics video digitizer board (SDD) is a candidate image processor.

Software must be written to drive the SDD board and the video disk player. This software could be written in Cromemco's Baseline software language now used for operation of the other S-Series graphics in the MSS. As an alternative to Baseline, it would be possible to use Interactive Television Corp.'s (ITC) Program Development Libraries (PDL) to operate the video disk player and video/graphics overlay processor. The PDLs are hardware independant so they use a different and higher level language than Baseline. It is not known at this time if all the graphics commands in the FPS/PEN-AIDS software would have to be rewritten to use the PDL software. Concern has also been expressed over the limitations of the available disk space in the MSS. The PDLs and associated software would require approximately 10MB of disk space. This study assumes that the space can be made available or that the computer can be upgraded to use a larger disk.

There is another reason that makes the Cromemco MSS with an SDD board less attractive than some of the other options listed in Section 7. It would be very desirable from an operational point of view to have the computer piece the frames together to form a large FOV mosaic even if the extra resolution gained by mosaicing is not necessary, and the Cromemco SDD be too slow to do the mosaicing effectively. While there is no question that higher resolution images are easier to read when printed on the hardcopy output, the lower resolution available directly from the DMA Laserdiscs is sufficient for use of the map. The SDD does not have the high resolution, rotation, mosaicing and scanning capabilities, nor the speed required for this application. Images are normally combined on a more sophisticated and expensive video processor than the Cromemco SDD. The Parallax 1280, that would require extensive reprogramming of the established Cromemco Baseline video software. It would be possible to produce the composite image on the Cromemco in software, but it would require extra programming since this is not a standard Baseline operation and it would be slower than the Parallax 1280, so use of the Cromemco MSS with an SDD is not recommended for the mission planning workstation.

7.2 MICROVAX II BASED WORKSTATIONS

Using a computer such as the MicroVAX II for the mission planning workstation results in extensive disk space, high processing speed and resolution, large software base, good documentation, high reliability and extensive hardware and software support. A MicroVAX II and Tektronix 4125 has been used for similar graphics-only workstations, but the 4125 is not applicable for displaying the video map background in this system since the 4125 only accepts graphics inputs in the form of vectors, and the video map information is very difficult to vectorize. For that reason, a video/graphics-overlay processor such as the Parallax 1280 and an RGB monitor are used instead of the 4125 for display of this information. The Parallax 1280 will perform all the required operations at a reasonable speed and cost, considerable software has been written for it and it has been in the field long enough to have established a good reliability record. Several system integrators have used the MicroVAX II/Parallax 1280 as the basis of their workstations. These workstations are reviewed below.

7.2.1 Martin Marietta MWS

The Martin Marietta Modular Workstation (MWS) is a hardware and software package based on the VAXstation II/GPX, a Parallax 1280 and a GKS Level 2c graphics software package from Nova Graphics (GKS graphics software to drive the Parallax 1280 is also available from Advanced Technology Center). All modules are mounted in transit cases and EMC is specified to MIL-STD-461B, Part 4. Their Modular Workstation has the windowing capability of the GPX, but uses standard RGB monitors for the menus so it can be used in a single-monitor configuration if desired. For the map storage, Martin Marietta's workstation uses a choice of magnetic disk, a WORM drive or Sony LDP 2000/1 Laserdisc player. Other than the GKS and map indexing software, little map manipulation software is available from Martin Marietta at this time. This system, along with a color copier, would form the basis for a good mission planing workstation. The recommended configuration for this application would use the dual-monitor display and the Laserdisc drive.

7.2.2 Fairchild Maps 300

In their MAPS 300 system Fairchild uses the MicroVAX II, a VT220 terminal, a trackball for graphics input and a Parallax 1280. The Parallax 1280 board mounted in the MicroVAX is used with an Ikegami 16 inch diagonal 1280x1024 pixel resolution monitor. The Parallax graphics software is used with no GKS interface.

Fairchild does not have DMA map disk indexing and manipulation software available for this system since the paper maps are digitized directly and no Laserdiscs are used. DMA paper maps and reconnaissance photos or other imagery are digitized by an outside firm. Current digitizing resolution is 130 pixels per inch (ppi), but Fairchild plans to go to 150 ppi since the printer is a 300 ppi Versatec Versacolor thermal transfer model. By changing to 150 ppi, the printed image could be made by a simple pixel replication method. A Versatec Model 126 interface is used for the MicroVAX's Q-Bus connection.

Fairchild's mission planning system stores its digitized map images on a Maxtor write-once-read-many (WORM) optical disk drive with a capacity of 400 MB on each side. The system may be ordered with two of the drives if desired. The software runs under Digital Equipment Corporation's VMS operating system.

This system would form the basis for a good mission planing workstation when digitized maps with the required coverage become available, but the system does not presently have the capability to use videodisks. A Laserdisc hardware and software suite could be added for use of the presently-available DMA videodisks. The graphics software is not writen in GKS, and the structure and modularity of the optical disk manipulation software is not known, so no estimate of the cost of adding a videodisk capability to the Fairchild MAPS system can be given at this time.

7.3 LOGICON ACMFS

This prototype Automated Combat Mission Folder System was developed for Headquarters, SAC. The prototype was developed using digitized maps, an IBM mainframe computer and a 400 dpi printer. It is a CMF hardcopy generation system and does not contain mission planning software. The DMA charts are optically scanned and digitized. The compressed data is stored on optical disks. The mission flight plan is communicated to the ACMFS via 9-track tape or interactive operator inputs. The digitized map images may then be rotated and pieced together as necessary so that the appropriate annotations can be overlayed on the maps. The resulting maps are then stored on disk and printed as a sequenced set.

The 400 dpi resolution used by ACMFS is more than is required for this application and results in unneccessary expense, processing time and data storage requirements, so the system is not recommended as the basis for a mission planning workstation.

7.4 DECISIONS AND DESIGNS IADS

DDI's Integrated Automated Display System is a command and control workstation developed by the Joint Cruise Missile Projects Office. It integrates data from several sources and can superimpose it on a DMA videodisk map background. The display resolution is 512 x 512 pixels and 8 bits are used for color information. Custom maps can be composed by using stored feature separates . That is, seperate map overlays may contain all the rivers or all the roads in the map. These feature seperates may be overlayed to form a custom map containing only the desired types of information or the overlays may be combined with DMA maps. The map data base for these feature separates includes Korean, Middle Eastearn, Caribbean and Alaskan areas. DTED is used to provide a display of the area that can be used to obtain a manually-entered route. The DTED is used to provide a vertical-clearance-based color difference to the map display so that the planner can use his visual perception to avoid clobber and minimize radar exposure.

The IADS system is not recommended since it does not have the high resolution graphics, rotation, mosaicing and scanning capabilities required for this application.

APPENDIX A

AVAILABLE ANALOG MAP DISKS

It should be noted here that map disks made for different agencies do not necessarily use the same indexing software for retrieving the images. There is no standard across the industry so it would be best to use the video disks produced for DMA by ITC.

16 FEB 1986

DMA POLICY
FOR
DEVELOPMENT OF A STANDARD PRODUCT
FOR MAPPING, CHARTING AND GEODESY VIDEO DISCS

1. Mapping, Charting and Geodesy (MC&G) video discs as a DMA standard product have been approved by the Director of DMA. This new standard product provides worldwide coverage and consists of 39 video discs. Production will be accomplished by contract with a target award date of mid-February 1986 and a completion date of September 1987.

2. Issues considered in the development of MC&G video discs were:

a. Area coverage and product inclusion:

- First disc (200 copies) will provide world coverage using a variety of small scale maps.

- Remaining 38 discs (150 copies each) will be produced on a regional or country basis. Discs will contain images of DMA and co-producer ONC's, TPC's, JOG-G's, 1:50K (over border and high interest areas), and city products/ports and harbors.

b. Product content ratio (Percent of available product coverage used):

Product	Percent
ONC	100
TPC	100
JOG-G	100
1:50K	10
Cities/ Ports and Harbors	5

c. Indexing software now includes:

- VAX 11/780
- APPLE PLUS (MICROFIX)
- IBM PC

d. Resolution of geographic vs UTM indexing system:

- Geographic indexing system will be used.

e. <u>Referencing system concept:</u>

- Map/chart products will be filmed along lines of latitude.

f. <u>Product format to provide best presentation:</u>

- Format will be oriented on a regional rather than a product basis.

g. <u>Definition of a maximum product field-of-view (FOV):</u>

- 3" FOV (good resolution)
- 6" FOV (Marginal resolution but still readable - used for orientation only)
- 8" FOV (Poorer resolution - small type not readable - used for orientation only)

h. <u>Preparation of a DMA MC&G video disc product specification:</u>

- First draft by 28 April 1986
- Coordination and approval by 31 May 1986
- Finished and printed by 30 June 1986

3. A signed contract is expected by mid-February with the first disc (small scale world coverage) due 93 days after award of contract. One additional disc shall be delivered each 2 week period thereafter, until the remaining 38 discs are provided.

UNITED STATES GOVERNMENT

memorandum

DATE: 11 FEB 1986

REPLY TO ATTN OF: PPL

SUBJECT: Defense Mapping Agency (DMA) Mapping, Charting & Geodesy (MC&G) Video Disc

TO: PR

1. Reference PR memorandum dated 5 November 1985, subject as above.

2. As requested at the reference, the following video disc delivery schedule is provided for your information and is based on the contract initiation date of 5 February 1986:

Quarters after AOC	Materials due Date	Required Products & Area of Coverage
1st	9 April 1986	World
	23 April 1986	Central America North
	7 May 1986	Central America South
	21 May 1986	South America North
	4 June 1986	South America Central
2nd	18 June 1986	Argentina North, Chile North
	2 July 1986	Argentina-Central Chile Central
	16 July 1986	Argentina South-Chile South
	30 July 1986	Caribbean
	13 August 1986	Middle East
	27 August 1986	Egypt and Sinai
	10 September 1986	Syria to Saudi Arabia
	24 September 1986	Southern Arabia
3rd	8 October 1986	Eastern Mediterranean
	22 October 1986	North Africa
	5 November 1986	Libya
	19 November 1986	Iraq and Western Iran
	3 December 1986	Iran
	17 December 1986	Kuwait & Southern Oil Fields

OPTIONAL FORM NO. 10
(REV. 1-80)
GSA FPMR (41 CFR) 101-11.6
5010-114

U.S. GOVERNMENT PRINTING OFFICE : 1982 O - 361-526 (4311)

Quarters after AOC	Materials due Date	Required Products Area of Coverage
3rd	31 December 1986	Northern India
	14 January 1987	Southern India & Sri Lanka
	28 January 1987	Thailand & Borders
4th	11 February 1987	Laos & Kampuchea
	25 February 1987	Vietnam & Borders
	11 March 1987	Afghanistan
	25 March 1987	Western China
	8 April 1987	Southeastern China
	22 April 1987	Eastern China/Russian Border
	6 May 1987	Eastern China & Korea
	20 May 1987	Germany & Poland
5th	3 June 1987	Southern Europe
	17 June 1987	Philippines & Taiwan
	1 July 1987	Sumatra & Malaya
	15 July 1987	US & Cities
	29 July 1987	US West
	12 August 1987	Texas Border
	26 August 1987	Mississippi Delta
	9 September 1987	Classified
	23 September 1987	Classified

3. PPL point of contact is Mr. Stuart Coleman, 31401.

THOMAS O. SEPPELIN
Assistant Deputy Director for
Production and Distribution

A.2 INTERACTIVE TELEVISION CORPORATION MAP DISKS

Videodisc Map Products: Completed

	Title	Classification	Agency
1.	USSR: Eastern Region	Unclassified	COINS
2.	USSR: Central Region	Unclassified	COINS
3.	USSR: Western Region	Unclassified	COINS
4.	TCO Test Bed	Unclassified	BDM
5.	The World	Unclassified	DMA
6.	USS Carl Vinson	Unclassified	CCA
7.	Central America: North	Unclassified	DMA
8.	Central America: South	Unclassified	DMA
9.	Federal Railroad Administration	Unclassified	DMA
10.	South America: North	Unclassified	DMA
11.	South America: Central	Unclassified	DMA
12.	Argentina North - Chile North	Unclassified	DMA
13.	Argentina Central - Chile Central	Unclassified	DMA
14.	Argentina South - Chile South	Unclassified	DMA
15.	Caribbean	Unclassified	DMA
16.	Cyprus and the Middle East	Unclassified	DMA
17.	Egypt and Sinai	Unclassified	DMA
18.	Syria to Saudia Arabia	Unclassified	DMA
19.	Northeastern Africa	Unclassified	DMA
20.	Libya	Unclassified	DMA
21.	Iraq and Western Iran	Unclassified	DMA
22.	Iran	Unclassified	DMA
23.	Kuwait and Southern Oil Fields	Unclassified	DMA
24.	Korea	Unclassified	COINS
25.	Korea	Secret/NF/WN	COINS
26.	Afghanistan	Unclassified	DMA
27.	Eastern China and Korea	Unclassified	DMA
28.	European Theater	Unclassified	IDA
29.	Southern Arabia	Unclassified	DMA
30.	Germany and Poland	Unclassified	DMA
31.	Southern Europe and the Azores	Unclassified	DMA
32.	US Eastern Seaboard	Unclassified	RTSI
33.	Northern India	Unclassified	DMA
34.	Southern India and Sri Lanka	Unclassified	DMA
35.	USSR: Mobile Missile	Unclassified	JNIDS
36.	USSR: Naval	Secret/NF	DMA
37.	Thailand	Unclassified	DMA
38.	Laos and Cambodia	Unclassified	DMA
39.	Vietnam	Unclassified	DMA
40.	Western China	Unclassified	DMA
41.	Southeastern China	Unclassified	DMA
42.	Eastern China - Russian Border	Unclassified	DMA
43.	Soviet Union I	Secret/NSI	Sandia

A.2 INTERACTIVE TELEVISION CORPORATION MAP DISKS (CONT'D)

Videodisc Map Products: **In Progress**

	Title	Classification	Agency
1.	Soviet Union II	Secret/NSI	Sandia
2.	Soviet Union III	Secret/NSI	Sandia
3.	Soviet Union IV	Secret/NSI	Sandia
4.	Soviet Union V	Secret/NSI	Sandia
5.	West and East Germany I	Secret	DARPA
6.	West and East Germany II	Secret	DARPA
7.	Central America	Secret	COINS
8.	Phillipines and Taiwan	Unclassified	DMA
9.	Malaysia and Western Indonesia	Unclassified	DMA
10.	United States and Cities	Unclassified	DMA
11.	Southwestern US and Mexico	Unclassified	DMA
12.	Texas/Mexico Border	Unclassified	DMA
13.	Missippi Delta	Unclassified	DMA
14.	Eastern Mediterranean	Unclassified	DMA
15.	Mediterranean	Secret	DMA
16.	South America/Africa	Secret	DMA

Thermal transfer printers are more reliable than ink jet printers, therefore, thermal transfer is preferred. The more limited temperature range of thermal transfer hardcopy versus ink jet hardcopy is not expected to pose operational problems. If the current lack of tempest certification on the printer can be accepted, a Versatec Versacolor or Mitsubishi G650 300 dpi thermal transfer printer would be an excellent device for present and future efforts.

A.3 PERCEPTRONICS

Laser Video Map Disc Price List

1. Standard Discs in Stock

A. Laser Video Mapping System Compatible (Ship 15 days from P.O.)

Description	Price
DCCS-OC-111 (Ft. Lewis, Yakima area)	$1000.00
European Theatre	$1000.00
Korea-1 (2.0) (DMZ area)	$1000.00
Aquila	$1000.00
V Corps (2.0) (Middle Germany North)	$1000.00
Honicel (Central America: Hond., El Salv., Nic.)	$1000.00
Corp of Engineers - two sided	$2000.00
Austrailian BABAS - two sided	$2000.00

B. Laser Video Mapping System Compatible, but require Index System Development at additional charge. (Ship 30 days from P.O.)

Description	Price
CATTS/MACE (Fulda Gap, Sinai, Ft. Irwin)	$1000.00
Northern A/G (2.0) (Northern Germany)	$1000.00
Korea-1 (2.0)	$1000.00
Korea-2 (2.0)	$1000.00
Korea-3	$1000.00
Korea-4	$1000.00
Korea-5 (2.0)	$1000.00
Southern Germany (2.0)	$1000.00
Southwest Asia-3 (2.0)	$1000.00
VII Corps (2.0) (Midd[illegible] Germany South)	$1000.00
Southwest Asia-1 (2.0)	$1000.00
Southwest Asia-2 (2.0)	$1000.00
Southwest Asia-4 (2.0)	$1000.00
Southwest Asia-5 (2.0)	$1000.00
Southwest Asia-6 (2.0)	$1000.00
Central America	$1000.00
CONUS Training Areas - two sided	$2000.00
Caribbean	$1000.00
JTLS - Southwest Asia	$1000.00
JESS - Korea - 1	$1000.00
JESS - Korea - 2	$1000.00
* Hokkaido, Japan	$1000.00
* Japan and Taiwan	$1000.00
* Luzon, Philippines	$1000.00
* Philippines (South of Luzon)	$1000.00
* The Kuril Islands (Kamchatka, Kurils, Sakhalin)	$1000.00
* Thailand (North of 14 30 N)	$1000.00
* Thailand (South of 14 30 N)	$1000.00
** Laos, Cambodia, Vietnam and Bangladesh	$1000.00
** Aleutians, USSR (E. of 100 E) and China (S. of USSR)	$1000.00

* Available after September 30, 1986
** Geographic area may differ from description

2. Video Map Disc Development

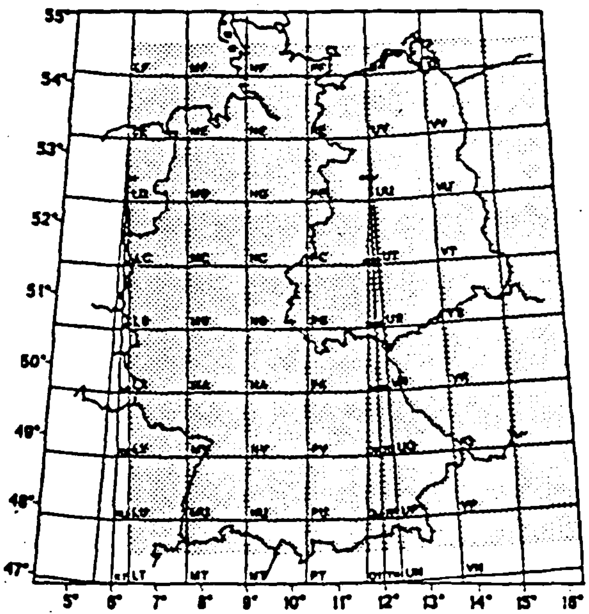
Call for custom pricing.

A.3.1 Perceptronics Map Coverage and Scales Example

PERCEPTRONICS VIDEO MAP DISC SOUTHERN GERMANY 2.0 CONT.

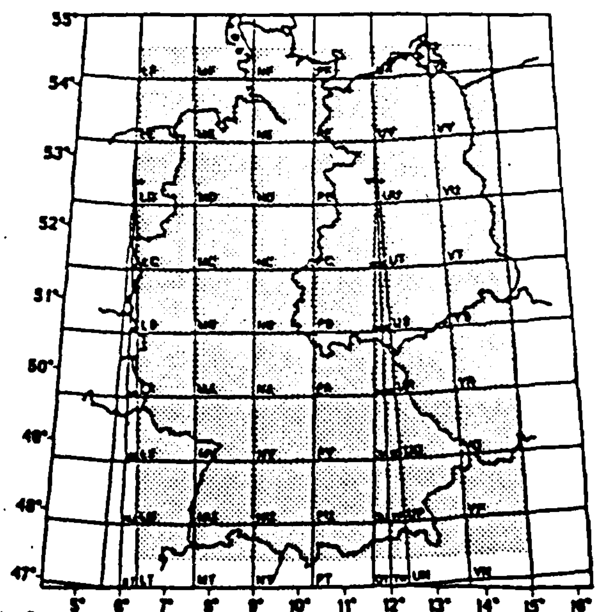
1:1,000,000 MITTELEUROPA MAP

FIELDS OF VIEW (KM):	STEP:	#IMAGES:
200x150	25x25	990
100x75	25x25	1122
50x37.5	20x20	1804



1:1,000,000 MILITARY DISTRICTS MAP

FIELDS OF VIEW(KM):	STEP(KM):	#IMAGES:
200x150	25x25	627
100x75	25x25	726



PERCEPTRONICS VIDEO MAP DISC   SOUTHERN GERMANY   VERSION 2.C

1:60,000,000 WORLD MAP

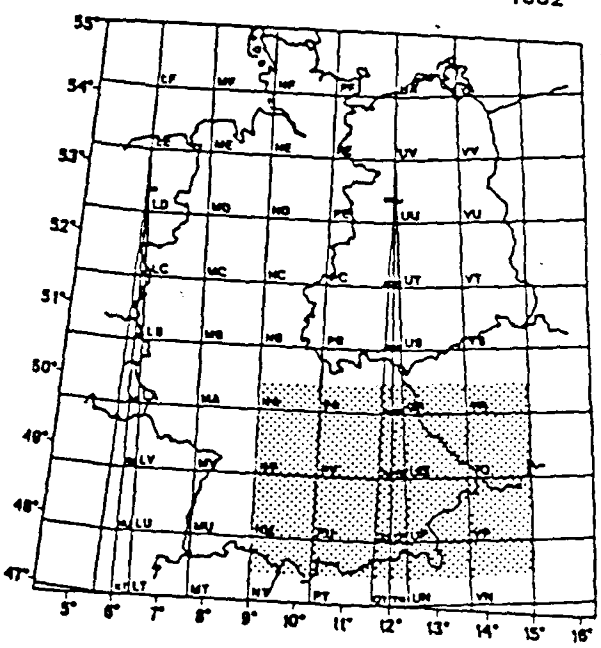
FIELDS OF VIEW(KM):	STEP(KM):	#IMAGES:
6300x4725	2500x2000	288
3000x2250	1800x1200	650

1:30,000,000 WORLD MAP

FIELDS OF VIEW(KM):	STEP(KM):	#IMAGES:
5000x3750	2500x2000	288
3000x2250	1500x1000	868

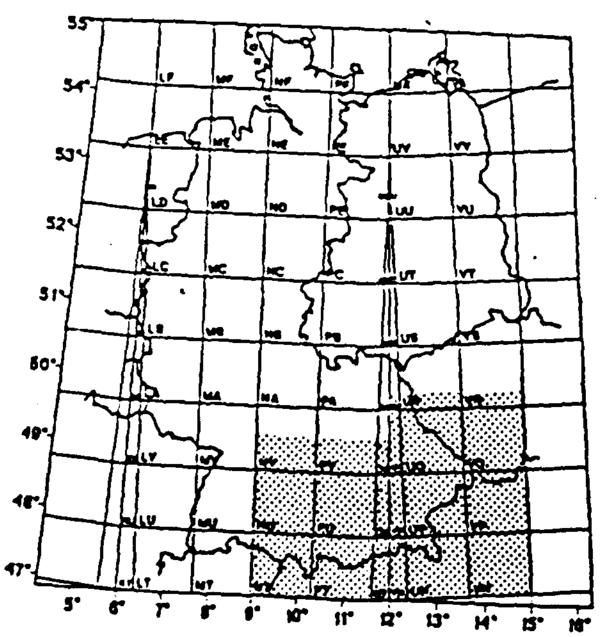
1:500,000 ROAD MAP

FIELDS OF VIEW (KM)	STEP (KM)	# IMAGES
35x26.3	10x10	1302



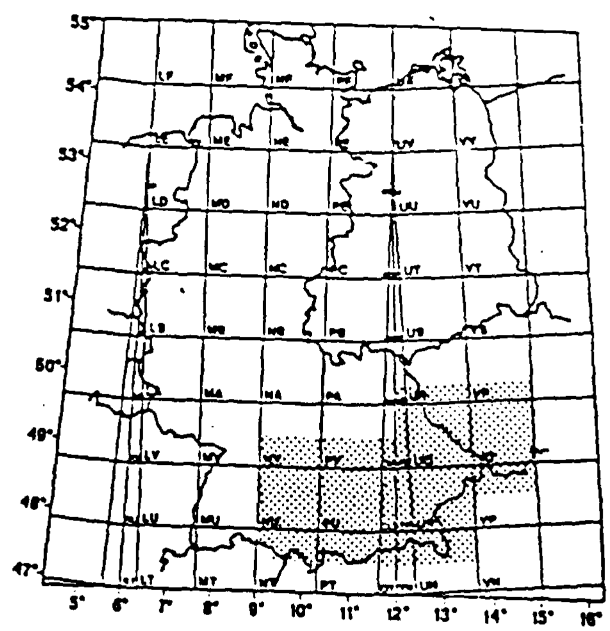
1:250,000

FIELDS OF VIEW (KM)	STEP (KM)	# IMAGES
10x7.5	5x4	6394



1:50,000

FIELDS OF VIEW (KM)	STEP (KM)	
8x6	6x4	4097
3x2.25	2x1.5	32036



APPENDIX B

TACTICAL OPTICAL DISK SYSTEMS (TODS); RADC

This appendix provides a summary of a study of optical disk drives that was performed by the Rome Air Development Center. The summary is included here at the request of USAFE.

The TODS study concluded that:

1. The projected storage cost per bit is now lower than that of magnetic and semiconductor memory, will remain lower at least through 1990, and will retain its cost advantage in the future.

2. The capacity of optical disks is at least as high as Winchester (or fixed, magnetic) disks, while the transfer rate for retrieval of the stored information is equivalent to that of Winchester technology.

The TODS study contained a table comparing eleven optical disk drives, some of which are covered in this report. The table is interesting as a comparison of many commercially available optical disk drives, although the Maxtor RXT-800S, recommended in this report, is still preferred since it has a large storage capacity for a 5 inch drive and a high transfer rate.

GLOSSARY OF ACRONYMS AND ABBREVIATIONS

ACMFS:	Logicon's Automated Combat Mission Folder System. See Section 7.3.
CDROM:	Compact disk read-only memory. A 5" optical disk.. See Section 6.2.2.3.
CMF:	Combat mission folder. A comprehensive package of materials used to assist the aircrew in pre-mission preparation and inflight conduct of the mission. See Sections 1, 2, 5, 6.1.1.1.
DMA:	Defense Mapping Agency. See Sections 1, 6.1.1.1, 6.1.3, 6.1.4.
DOS:	Disk Operating System. A computer operating system used by IBM personal computers. See Section 6.2.2.3.
dpi:	Dots per inch. A measure of the resolution of a printer. See Section 6.3.3.
DTED:	Digital terrain elevation data, supplied by DMA. See Section 7.4.
FOV:	Field of view. The area that an image encompasses. See Section 6.1.1.1.
FPS:	Flight Planning System. A set of mission planning software modules osed by the TAF MSS. See Section 7.1.
GB:	Gigabyte. One trillion eight-bit pieces of information.
GKS:	Graphical Kernel System. A device-independent graphics programming language. See Section 6.4.6.5.
IADS:	DDI's Integrated Automated Display System. See Section 7.4.
ITC:	Interactive Television Company. See Sections 6.1.4, 6.4.6.5.
K:	Thousand.
MAPS:	Fairchild Mission Analysis and Planning System. See Sections 2, 7.2.2.
MB:	Megabyte. One million eight-bit pieces of information.
MC&G:	Mapping , charting and geodesy. See Section 6.1.3.
mS:	Milliseconds. One thousandth of one second.
MSS:	Cromemco-based Mission Support System developed for the Tactical Air Forces. See Sections 2, 7.1.
MWS:	Martin Marietta's Modular Workstation. See Section 7.2.1.
PC:	Personal Computer.
PDL:	ITC's Program Development Libraries. See Sections 6.4.6.5, 7.1.

pixel: Picture element. The smallest area of an image to be used to analyze the contents of the image. See Section 6.1.2.

ppi: Pixels per inch. A measure of the resolution of an image. See Section 7.2.2.

RADC; Rome Air Development Center. See Section 6.2, Appendix B.

RGB. Red-Green-Blue. A common interface used to drive a video monitor. See Section 5.

SCSI: Small Computer System Interconnect. A commonly used interface between computers and disk drives. See Section 6.2.2.4.

SDD: Cromemco's video digitizing image processor board. See Section 7.1.

TAF: Tactical Air Forces. See Section 2.

VMS: An operating system used by Digital Equipment Corporation computers. See Sections 6.2.2.1, 6.2.2.2, 6.2.2.4.

WORM: Write-once-read-many. See Sections 6.1, 6.1.2.

UNIX: A commonly used computer operating system originally developed by AT&T Bell Laboratories. See Section 6.2.2.3.